SEWAGE AND INDUSTRIAL WASTES

(Formerly Sewage Works Journal)

JOURNAL of the FEDERATION OF SEWAGE AND INDUSTRIAL WASTES ASSOCIATIONS

Special Features

Physical Behavior of Syndets—Lynch and Sawyer

Thermophilic Digestion at Los Angeles—Garber

Refinery Wastes Treatment—Mau

Niagara Boundary Waters Pollution—Black and Devendorf

OCTOBER, 1954—VOL. 26, No. 10

Still available . . .

TWENTY-YEAR INDEX

SEWAGE WORKS JOURNAL

(now SEWAGE AND INDUSTRIAL WASTES)

1928—1948

AUTHORS • SUBJECTS • GEOGRAPHICAL

Here is the key to the great reservoir of fundamental knowledge that is stored in the 115 numbers of the JOURNAL that record the era of greatest progress in water pollution control. Almost 9000 entries are compiled and arranged for finger-tip location with maximum convenience and economy of time. This compendium covers completely the entire content of the first twenty volumes of the JOURNAL. Bound in buckram, 144 pages.

Price—$4.50

Order your copy now from

FEDERATION OF SEWAGE AND INDUSTRIAL WASTES ASSOCIATIONS

325 ILLINOIS BUILDING CHAMPAIGN, ILLINOIS

NOW - A Teammate for the COMMINUTOR

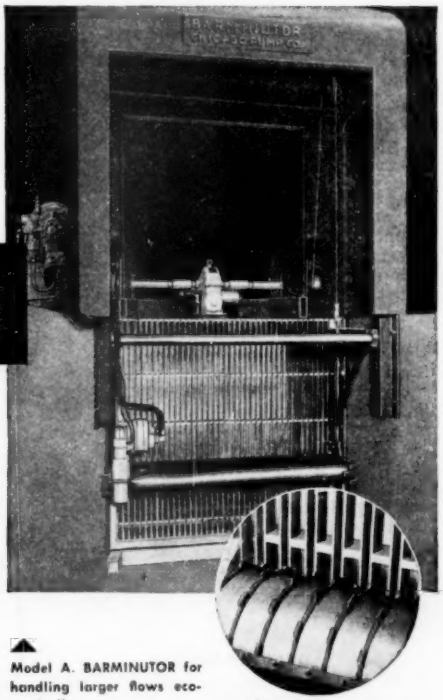
THE BARMINUTOR

Gives Same Clean, Continuous Disposal of Coarse Sewage Matter . . . without Removal from Channel

No disposal problems, no unpleasant servicing — the BARMINUTOR cuts all coarse sewage material into small, easily settleable solids — without removal from the channel. Eliminates raking, burial, incineration and grinding. Operation is continuous; manual attention is unnecessary except for periodic lubrication, inspection and cutter sharpening. Power requirements are lower than for mechanically raked screens and grinders. And, since all cutting is done above the grit line, wear is greatly reduced.

IDEAL FOR TREATMENT PLANTS, PUMPING STATIONS, OUT-FALL SEWERS

The BARMINUTOR can be used in already established influent channels from one to twelve feet wide. No special basin or channel shape is required. Descriptive literature and engineering data is available on request.



Model A. BARMINUTOR for handling larger flows economically.

Close-up of cutters and combs. Cutters rotate within slots of both bar and comb.

EFFICIENCY PROVED

More Than 4000 COMMINUTORS Installed since their development by the Chicago Pump Company 19 years ago stand behind the BARMINUTOR. More than five years of actual operation preceded the installation of BARMINUTORS at a number of modern treatment plants. At the Indianapolis, Indiana Sewage Plant, a BARMINUTOR was subjected to test loads of screenings up to six times the normal 40 M.G.D. load. Comminution time: 6 minutes. Head loss: not in excess of 6".

CHICAGO PUMP COMPANY

SEWAGE EQUIPMENT DIVISION

622 DIVERSEY PARKWAY • CHICAGO 14, ILLINOIS

Flush Kleen, Screw-Feller, Plunger Horizontal and Vertical Non-Clogs Water Seal Pumping Units, Samplers

Swing Diffusers, Stationary Diffusers, Mechanical Aerators, Combination Aerator-Clarifiers, Comminutors

FEDERATION OF SEWAGE AND INDUSTRIAL WASTES ASSOCIATIONS

PRESIDENT

LOUIS J. FONTENELLI
Supervising Engineer
Rahway Valley Joint Meeting
Garwood, New Jersey

VICE-PRESIDENT

DAVID B. LEE
State Board of Health
P.O. Box 210
Jacksonville, Fla.

TREASURER

W. W. DEBERARD
Deputy Commissioner for Water
402 City Hall
Chicago 2, Illinois

EXECUTIVE SECRETARY-EDITOR

W. H. WISELY
325 Illinois Building
Champaign, Illinois

ADVISORY EDITOR

F. W. MOHLMAN
Director of Laboratories
The Sanitary District of Chicago
910 S. Michigan Ave.
Chicago, Illinois

DIRECTORS

Alabama: J. C. CLARKE (1954)
Arizona: LEIGH O. GARDNER (1955)
Arkansas: GLEN T. KELLOGG (1955)
California: F. G. NELSON (1956)
Canada: NICOL MACNICOL (1955)
Central States: W. D. HATFIELD (1954)
Dakota: R. J. STAPP (1955)
Federal: L. B. DWORSKY (1956)
Florida: J. E. KIKER, JR. (1956)
Georgia: C. E. DRUMMOND (1956)
Germany: F. SIERP (1956)
Inst. San. Eng. (Eng.): W. F. BROWN (1956)
Inst. Sew. Pur. (Eng.): W. F. FREEBORN (1956)
Iowa: H. S. SMITH (1956)
Kansas: G. E. MAU (1954)
Kentucky-Tennessee: F. W. KITTRELL (1955)
Louisiana: J. J. HOLTGREVE (1955)
Maryland-Delaware: W. M. BINGLEY (1954)
Michigan: CLYDE L. PALMER (1955)
Missouri: W. G. RIDDLE (1954)
Montana: F. F. PALMER (1956)
Nebraska: T. A. FILIPI (1955)
New England: W. H. BROWN, JR. (1954)
New Jersey: HENRY VAN DER VLIET (1954)
New York: W. H. LARKIN (1954)
North Carolina: P. D. DAVIS (1955)
Ohio: T. C. SCHAETZLE (1954)
Oklahoma: C. E. MOUTREY (1956)
Pacific Northwest: E. C. JENSEN (1956)
Pennsylvania: HOWARD T. REUNING (1955)
Puerto Rico: L. R. ROBLES (1956)
Rocky Mountain: C. G. CALDWELL (1954)
South Carolina: T. E. ROBERTSON, JR. (1955)
Sweden: NILS WESTBERG (1956)
Switzerland: EDUARD HOLINGER (1955)
Texas: E. W. STEEL (1954)
Virginia: B. L. STROTHER (1956)
West Virginia: R. F. ROCHELEAUX (1956)
At Large: R. G. TYLER (1954)
At Large: KERWIN L. MICK (1955)
At Large: V. MACKENZIE (1956)
W. and S. Wks. M/grs.: R. S. RANKIN (1954)
W. and S. Wks. M/grs.: HARRY E. SCHLENZ (1955)
W. and S. Wks. M/grs.: W. A. HARDENBERGH (1956)
Ex-Officio: E. SHERMAN CHASE
Ex-Officio: M. M. COHN
Ex-Officio: H. W. STREETER
Ex-Officio: F. W. GILCREAS
Ex-Officio: H. HEUKELEKIAN
Ex-Officio: W. J. ORCHARD
Ex-Officio: G. P. EDWARDS

SEWAGE AND INDUSTRIAL WASTES

REG. U. S. PAT. OFF.

A monthly Journal devoted to the advancement of fundamental and practical knowledge concerning the nature, collection, treatment and disposal of sewage and industrial wastes, and the design, construction, operation and management of such works.

PUBLICATION OFFICE

Prince and Lemon Sts., Lancaster, Pa.

EDITORIAL AND EXECUTIVE OFFICES

325 Illinois Bldg., Champaign, Ill. Send all manuscripts, advertising copy, subscriptions, address changes, etc. to this address.

SUBSCRIPTION RATES

Members of local sewage works associations affiliated with the Federation, $5.00 per year.

Non-members: U. S. and Canada, $7.50 per year; other countries, $9.00. (Foreign subscriptions must be accompanied by International Money Order.)

Single copies: United States $1.00 each; Foreign, $1.25 each.

CLAIMS

No claims will be allowed for copies of Journals lost in the mails unless such claims are received within sixty (60) days of the date of issue and no claims will be allowed for issues lost as a result of insufficient notice of change of address. "Missing from files" cannot be accepted as the reason for honoring a claim.

MAILING PERMIT

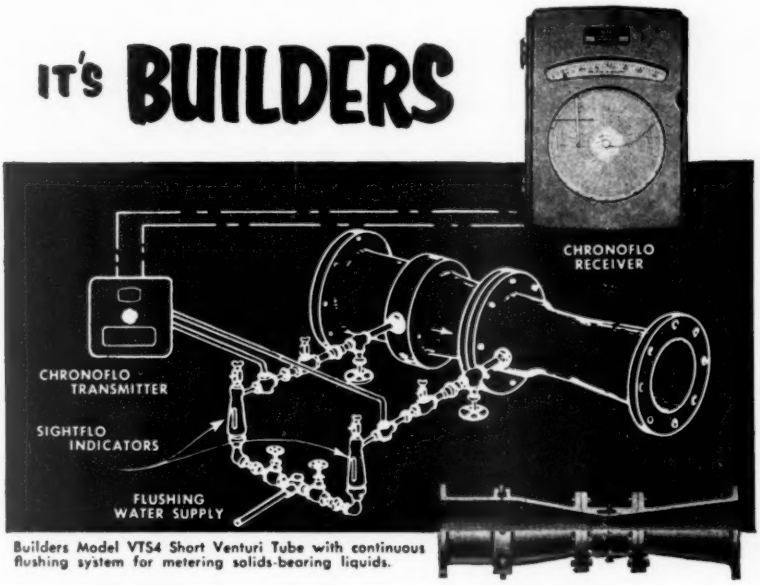
Entered as second-class matter, May 7, 1934, at the post office at Lancaster, Pa., under the Act of March 3, 1879. Accepted for mailing at the special rate of postage provided for in the Act of February 28, 1925, embodied in paragraph (d-2), Section 34.40, P. L. & R. of 1948, authorized October 4, 1945.

REFERENCE SERVICE

Sewage and Industrial Wastes is indexed regularly by *Industrial Arts Index* and *Engineering Index*.

Microfilm copies of this Journal may be procured from University Microfilms, Ann Arbor, Mich. This service is limited to regular subscribers only.

IT'S BUILDERS



Builders Model VTS4 Short Venturi Tube with continuous flushing system for metering solids-bearing liquids.

...for the complete metering "package"

BUILDERS CHRONOFLO SYSTEM

for electrical transmission of flow information over any distance. Bulletin 230-K24.

BUILDERS VTS4 SHORT VENTURI TUBE

accurate, low loss of head, economical. Bulletin 110-K11.

BUILDERS CONTINUOUS FLUSHING SYSTEM

eliminates manual cleaning, improves metering efficiency. Bulletin 110-G1.

Builders offers a unique service to sewage and industrial waste treatment plants — *the complete line* of equipment for metering liquid flows . . . from the Venturi Tube in the pipe line to the Chronoflo metering instrument in the control panel. Find out about Builders metering "packages". For Bulletins, write Builders-Providence, Inc., 368 Harris Avenue, Providence 1, Rhode Island.

BUILDERS-PROVIDENCE

DIVISION OF B-I-F INDUSTRIES, INC.

BUILDERS IRON FOUNDRY • PROPORTIONEERS, INC. • OMEGA MACHINE CO.

BIF METERS FEEDERS CONTROLS

FSIWA MEMBER ASSOCIATIONS

Alabama Water and Sewage Assn.*
PROF. W. L. SAMUEL, *Secretary*
Alabama Polytechnic Institute
Auburn, Alabama

Arizona Sewage and Water Works Assn.*
QUENTIN M. MEES, *Sec.-Treas.*
721 N. Olsen
Tucson, Ariz.

Arkansas Water and Sewage Conf.*
DR. HARRISON HALE, *Sec.-Treas.*
c/o Southern State College
Magnolia, Ark.

California Sewage and Industrial Wastes Assn.
J. C. MALLERY, *Sec.-Treas.*
4822 N. Dunsmore Ave.
La Crescenta, Calif.

Canadian Institute on Sewage and Sanitation
DR. A. E. BERRY, *Sec.-Treas.*
Ontario Dept. of Health
Parliament Bldgs.
Toronto 8, Ontario, Canada

Central States Sewage and Industrial Wastes Assn.
GEORGE F. BERNAUER, *Sec.*
Room 453 State Office Bldg.
Madison 2, Wis.

Dakota Water and Sewage Works Conf.

*North Dakota Section**
JEROME H. SVOBE, *Sec.-Treas.*
c/o State Dept. of Health
Bismarck, N. Dak.

*South Dakota Section**
CHARLES E. CARL, *Sec.-Treas.*
c/o Div. of Sanitary Engineering
State Board of Health, Pierre, S. Dak.

Federal Sewage Research Assn.
LLOYD W. GEBHARD, *Sec.-Treas.*
Rm. 4220, Health, Education & Welfare Bldg., So.,
Washington 25, D. C.

Florida Sewage and Industrial Wastes Assn.
M. E. DAWKINS, *Sec.-Treas.*
P. O. Box 210
Jacksonville 1, Fla.

Georgia Water and Sewage Assn.*
A. T. STOREY, *Sec.-Treas.*
1210 Hemphill Ave., N.W.
Atlanta, Ga.

(Germany) Abwassertechnische Vereinigung
OTTO PALLASCH, *Sec.-Treas.*
Theaterstrasse 24,
Bonn, Germany

Institute of Sewage Purification
W. F. FREEBORN, *Sec.*
34 Cardinal's Walk,
Hampton-on-Thames, Middlesex, England

Institution of Sanitary Engineers
ERNEST V. BALSOM, *Secretary*
118 Victoria St.
Westminster, S. W. 1, London, England

Iowa Sewage Works Assn.
L. F. SKORCZESKI, *Sec.-Treas.*
207 South 15th Ave.
Marshalltown, Iowa

Kansas Sewage and Industrial Wastes Assn.
ROBERT H. HESS, *Sec.-Treas.*
Supt. of Water and Sewage Treatment
City Building
Wichita 2, Kansas

Kentucky-Tennessee Industrial Wastes and Sewage Works Assn.
R. PAUL FARRELL, *Sec.-Treas.*
420 Sixth Ave., N., Nashville 3, Tenn.

Louisiana Conference on Water Supply and Sewerage*
GEORGE H. WEST, *Sec.-Treas.*
P. O. Box 15, Water Dept., Lake Charles, La.

* Sewage Works Section.

Maryland-Delaware Water and Sewerage Assn.*
W. M. BINGLEY, *Sec.-Treas.*
2411 N. Charles St., Baltimore 18, Md.

Michigan Sewage and Industrial Wastes Assn.
D. M. PIERCE, *Sec.-Treas.*
Michigan Dept. of Health
Room 334, Admin. Bldg., Lansing 4, Michigan

Missouri Water and Sewerage Conf.*
WARREN KRAMER, *Sec.-Treas.*
c/o State Office Bldg., Sixth Floor
Jefferson City, Mo.

Montana Sewage and Industrial Wastes Assn.
HARVEY W. TAYLOR, *Sec.-Treas.*
Morrison & Maierle Inc.
Helena, Montana

Nebraska Sewage and Industrial Wastes Assn.
PAUL W. MOUSEL, *Secretary-Treasurer*
602 West B Street, McCook, Nebr.

New England Sewage and Industrial Wastes Assn.
STEPHEN M. HURLEY, JR., *Sec.-Treas.*
c/o State Dept. of Health
331 State Office Bldg., Providence, R. I.

New Jersey Sewage and Industrial Wastes Assn.
MICHAEL S. KACHORSKY, *Sec.-Treas.*
P. O. Box 766, Manville, N. J.

New York Sewage and Industrial Wastes Assn.
RALPH C SWEENEY, *Secretary*
c/o State Dept. of Health
21 N. Broadway, White Plains, N. Y.

North Carolina Sewage and Industrial Waste Assn.
E. C. HUBBARD, *Sec.-Treas.*
State Board of Health, Raleigh, N. C.

Ohio Sewage and Industrial Wastes Treatment Conf.
WARD E. CONRAD, *Sec.-Treas.*
301 Ohio Depts. Bldg., Columbus 15, Ohio

Oklahoma Water, Sewage and Industrial Wastes Conf.*
H. J. DARCEY, *Sec.-Treas.*
State Dept. of Health, Oklahoma City 5, Okla.

Pacific Northwest Sewage and Industrial Wastes Assn.
WALTER W. SAXTON, *Sec.-Treas.*
408 Old Capitol Bldg.
Olympia, Wash.

Pennsylvania Sewage and Industrial Wastes Assn.
B. S. BUSH, *Sec.-Treas.*
c/o Pennsylvania Dept. of Health
Kirby Health Center, Wilkes-Barre, Pa.

Puerto Rico Water and Sewage Works Assn.
ROBERT J. AULD, *Sec.-Treas.*
c/o Puerto Rico Aqueduct and Sewer Service
Box 2832, San Juan 12, Puerto Rico

Rocky Mountain Sewage Works Assn.
C. E. HARNESS, *Sec.-Treas.*
376 City and County Bldg., Denver, Colorado

South Carolina Water and Sewage Works Assn.*
W. T. LINTON, *Sec.-Treas.*
Wade Hampton Bldg., Columbia, S. C.

(Sweden) Föreningen För Vattenhygien
Erik Jonsson, *Secretary*
Box 5038, Stockholm 5, Sweden

(Switzerland) Verband Schweizerischer Abwasserfachleute
EDUARD HOLINGER, *Treasurer*
Spitzackerstrasse 17, Liestal, Switzerland

Texas Water and Sewage Works Assn.*
V. M. EHLERS, *Sec.-Treas.*
2202 Indian Trail, Austin, Tex.

Virginia Industrial Wastes and Sewage Works Assn.
J. L. HAMRICK, JR., *Sec.-Treas.*
415 W. Franklin St., Richmond 20, Va.

West Virginia Sewage and Industrial Wastes Assn.
GLEN O. FORTNEY, *Sec.-Treas.*
State Dept. of Health, Charleston, W. Va.

FOR ACCURATE REMOTE MEASUREMENT

of Flow, Liquid Level, Pressure

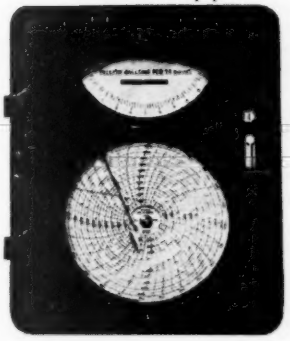
NEW! SIMPLEX ORTHOFLOW®

• Now you can transmit data accurately over great distances for instant reference at central or control points.

TRANSMITTER – Compact new electric unit actuates both in-plant and remote meters . . . unaffected by normal variations in voltage, temperature. Simple, dependable, rugged. Accuracy of ±2% at any point over wide flow ranges.

RECEIVER – Time-proven Simplex H Meter. Precisely duplicates transmitted data . . . automatically resets to correct data after power interruptions. Indicates, records, totalizes. Easy-to-read flow scale and chart.

WRITE FOR BROCHURE – Simplex Valve & Meter Company, 6719 Upland St., Philadelphia 42, Pa.



SIMPLEX®

VALVE AND METER COMPANY

MEMBER ASSOCIATION MEETINGS

Association	*Place*	*Time*
Pacific Northwest Sewage and Industrial Wastes Assn.	Hotel Eugene Eugene, Oregon	Oct. 21–23, 1954
Canadian Institute on Sewage and Sanitation	Windsor Hotel Montreal, P. Q. Can.	Oct. 25–27, 1954
New England Sewage and Industrial Wastes Assn.	Patterson Club, Fairfield, Conn.	Oct. 28, 1954
Rocky Mountain Sewage Works Assn.	Broadmoor Hotel, Colorado Springs, Colo.	Nov. 8–10, 1954
Florida Sewage and Industrial Wastes Assn.	Soreno Hotel, St. Petersburg, Fla.	Nov. 8–10, 1954
North Carolina Sewage and Industrial Wastes Assn.	George Vanderbilt Hotel, Asheville, N. C.	Nov. 8–10, 1954
West Virginia Sewage and Industrial Wastes Assn.	Hotel Prichard, Huntington, West Va.	Nov. 9–10, 1954
Nebraska Sewage and Industrial Wastes Assn.	Keystone Hotel, McCook, Nebraska	Nov. 11–12, 1954
Oklahoma Water, Sewage and Industrial Wastes Conf.	Student Union Bldg., Stillwater, Okla.	Nov. 15–20, 1954
New York Sewage and Industrial Wastes Assn.	Hotel Belmont Plaza, New York, N. Y.	Jan. 20–21, 1955
Arizona Sewage and Water Works Assn.	San Marcos Hotel, Chandler, Ariz.	April 14–16, 1955
California Sewage and Industrial Wastes Assn.	Mission Inn, Riverside, Calif.	April 27–30, 1955

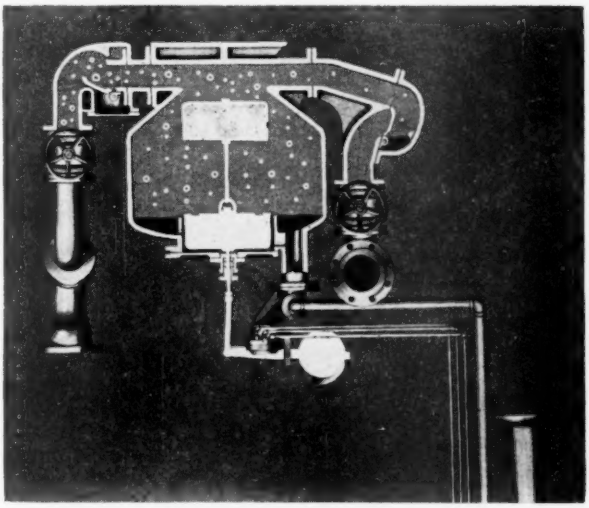
TWENTY-EIGHTH ANNUAL MEETING

Federation of Sewage and Industrial Wastes Associations
in conjunction with
New Jersey Sewage and Industrial Wastes Association
Ambassador Hotel, Atlantic City, New Jersey
October 10–13, 1955

Briefs from the YEOMANS GUARD

NOW!

Effective pre-aeration of wastes in the COLLECTING System



PRESAIRE* aeration mechanism—new development with Yeomans Pneumatic Ejectors improves aerobic condition of wastes in the collection system *before it reaches the treatment plant!*—combines a treatment function with a dependable, economical waste handling system.

PRESAIRE* aeration mechanism used with Yeomans Pneumatic Ejectors causes the air required for pumping to bubble through the waste fluid while under pressure with the result that at least two or three times more oxygen is dissolved in the sewage.

Advantages of PRESAIRE* aeration mechanism furnished *at no additional* cost with Yeomans Pneumatic Ejectors include:

1—Improved aerobic condition of sewage for better ultimate treatment at the plant.
2—Reduced B.O.D. loadings at the treatment plant because of higher oxygen content.
3—Added control and prevention of noxious odors.
4—Prevention of septicity in long and short force mains.
5—A shorter period of treatment at the plant since the wastes delivered are more ameniable to treatment.
6—Elimination of pre-aeration equipment in most cases.

* Patents Pending—a Yeomans trade mark

Write today for detailed information.

YEOMANS BROTHERS COMPANY
1999-7 N. RUBY STREET, MELROSE PARK, ILLINOIS
(Suburb of Chicago)

The test of a century

F.P.G.

This is Lancaster, Pa., County seat in one of the most highly cultivated farming districts in America.

Bettmann Archive

Old print showing southwest view of Lancaster about 100 years ago.

MODERNIZED **cast iron**

is the test that tells!

LANCASTER installed cast iron water mains 100 years ago . . . and installs them today.

Lancaster, Pa., has grown in 100 years from about 12,000 population to nearly 65,000 — but it has not outgrown the habit of buying cast iron pipe. From four miles of water mains a century ago, the present distribution system has increased to 105 miles of pipe—all of it cast iron pipe. Services have grown from 2,000 to nearly 20,000.

The word "test" means—"*put to the proof*"—according to the dictionary. Well, 60 utilities have put cast iron pipe to the *proof* for a century—a test to end all tests. They installed cast iron water or gas mains 100 years, or more, ago that are still in service. Yes, the test of a century has *proved* beyond question the long life and low cost per service year of cast iron pipe.

Cast iron pipe has been a rugged, long-lived product from the earliest days. Today's *modernized* cast iron pipe, centrifugally cast, is even stronger, tougher, and more uniform in quality. And, where needed and specified, it is centrifugally lined with cement mortar to assure sustained carrying capacity throughout the long life of the pipe.

Cast Iron Pipe Research Association, Thos. F. Wolfe, Managing Director, 122 So. Michigan Ave., Chicago 3.

This cast iron water main laid in 1835 by the Bureau of Water of Lancaster is still functioning after 119 years of service.

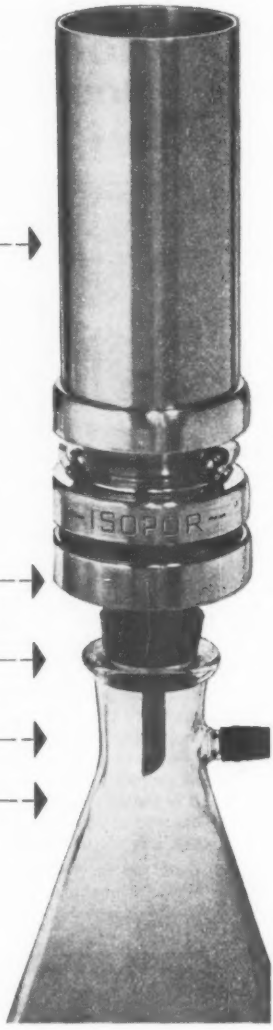
CAST Q IRON

The Q-Check stencilled on pipe is the Registered Service Mark of the Cast Iron Pipe Research Association.

pipe FOR MODERN WATER WORKS OPERATION

Announcing an entirely new

Molecular filter holder for bacteriological analysis of liquids



This new ISOPOR Holder for molecular filter membranes has been developed and perfected under the supervision of Dr. Alexander Goetz, international authority in the field of molecular membrane filtration. (J. Am. Waterworks Assoc., 43, 943-984 [1951]; 44, 471-483 [1952]; 45, 933-944, 1196-1210 [1953]; and others.)

Designed for maximum efficiency in either laboratory or field bacteriological analysis, this new ISOPOR MF Holder has many advantages over any other MF equipment previously available.

ADVANCED DESIGN—*The ISOPOR MF Holder is compact, efficient, easy to operate and sterilize. Overall height only 10¼", 500 ml capacity.*

STAINLESS STEEL CONSTRUCTION *eliminates corrosion, breakage, and necessity for gaskets which deteriorate under heat and with age.*

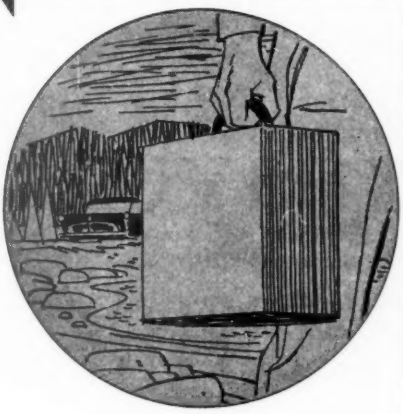
AUTOMATIC ADJUSTMENT—*Unique construction eliminates danger of damaging pressure on the MF membrane.*

STERILIZABILITY—*The ISOPOR MF Holder is not subject to autoclave damage. In addition, it is equipped for formaldehyde sterilization by the incomplete combustion of methyl alcohol, as described in literature (above).*

AG CHEMICAL COMPANY, INC.
P. O. Box 65C • Pasadena, California

FOR FIXED LABORATORIES

The ISOPOR MF Holder reduces time and expense in hydrosol analysis. No dilution necessary in most cases, high reliability of results, and MF membrane becomes permanent record. Using ISOPOR dehydrated nutrient schedules, standard tests can be completed in 16-18 hours without intermediate operations, using only two pieces of sterile equipment.



FOR FIELD ANALYSIS

The ISOPOR Water Laboratory, of which the ISOPOR MF Holder is a component, makes possible the performance of bacteriological water analysis in the field, away from laboratory facilities and independent of utilities (water, power, gas), with only one item of expendable supply (ISOPOR dehydrated nutrient schedules). The ISOPOR Water Laboratory is easily portable (only about 30 lbs. complete), contains *all* facilities and equipment for 24 independent hydrosol tests.

MAIL THIS COUPON FOR FURTHER INFORMATION

AG CHEMICAL COMPANY, INC.
Box 65C • Pasadena, California

Please send me further information and literature on

☐ ISQPOR MF Holder ☐ ISOPOR Water Laboratory
☐ ISOPOR Sterile Dehydrated Nutrient Packs

Name_____

Organization_____

Street Address_____ City_____ State_____

Patents Pending

See ISOPOR Ad on Page 417a

How to protect the taxpayer against the *"Weak Link"*

(How to protect the taxpayer against the "*Weak Link*," continued)

Here's a timely message to the men responsible for the investment of tax dollars in sewage works . . . the treatment plant as well as the sewer systems themselves

Investing tax dollars in sewage works is a very real responsibility—shared by every city official, engineer and operator. These men know that two outstanding wasters of the taxpayer's dollar are exorbitant treatment costs due to infiltration and sewer-maintenance costs due to root growth.

Many cities fight infiltration and root growth successfully . . . up to a point. They install Transite® Sewer Pipe with the tight Ring-Tite® coupling for the street-sewer lines. They know that, with Transite's tight joints, infiltration is sure to be kept far, far below the limits of even rigid specifications. And they know, too, that these tight joints lock out roots.

(How to protect the taxpayer against the "*Weak Link*," continued)

So far, so good. But such assurance does not go far enough—it goes only *up to a point!*

For there may be a "weak link" in this carefully planned program—the possibility that *the pipes which connect the homes to the street sewer* do not measure up to the standards of joint tightness set for the street sewers.

This network of sewer lines is also important in planning

This network of building-sewer lines is very extensive. It equals or exceeds the footage of the main system, with the result that—unless these pipes, too, have tight joints—this building-sewer network may function as a vast underground drainage system. In areas of high ground-water table and during seasonal rains, this excess infiltration is collected and dumped into the street sewers. This overloads the treatment plant . . . adds to the cost of treatment, *and defeats the very purpose of careful street sewer and treatment plant design.*

And to make matters worse, joints which permit infiltration also open the door to root growth—again adding to the expense and trouble.

(How to protect the taxpayer against the "*Weak Link*")

An important corrective step is being taken by many communities

Today progressive municipalities can take steps to make *every link* in the over-all sewer system a strong one. They can see to it, for example, that their codes specify, as do hundreds of codes throughout the country—the use of Johns-Manville Transite Building Sewer Pipe. This assures in the building-sewer lines the same joint tightness provided by Transite Sewer Pipe in the city street sewers.

You can take the immediate step of learning more about this asbestos-cement pipe with the tight joints that remove the weak link and give you the efficient, money-saving sewer system you plan it to be. Just fill out the coupon.

JOHNS-MANVILLE JM PRODUCTS **Johns-Manville TRANSITE PIPE**

Johns-Manville, Box 60, New York 16, N. Y.

Yes, let me have some of the facts about Transite Building Sewer Pipe, the strong asbestos-cement pipe with the tight Ring-Tite Coupling.

Name_____

Address_____

City_____ State_____

Two Bests

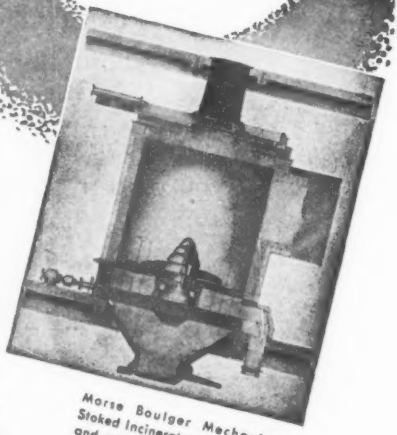
1
WASTE DISPOSAL BY INCINERATION

2
INCINERATORS BY SPECIALISTS

Select from this list of five different types and you will get the best type for your particular problem whether it is trash, garbage, sewage sludge, institutional organic matter . . . separately or in combination.

- **For Garbage and Rubbish**
  - **(1) Cell and Hearth**
  - **(2) Circular Hearth and Grates — Mechanically Stoked**
- **For Sewage Sludge Drying and/or Burning**
  - **(3) Multiple Zone Furnace—Mechanically Stoked**
- **For Garbage, Rubbish and Sewage Sludge**
  - **(4) Circular Unit, Mechanically Stoked, with Separate Compartment for Sewage Sludge Reduction**
- **For Garbage and Trash (Individual Buildings)**
  - **(5) Kernerators (Flue-Fed and Ready-Built)**

Our incinerator experience goes back nearly sixty years. Our work is guaranteed. Our incinerators are constructed under the supervision of our own field men who stay with it until the unit is in operation, fully broken in and crews instructed.



Morse Boulger Mechanically Stoked Incinerator, circular hearth and grate, for garbage, rubbish and all kinds of industrial wastes.

MORSE BOULGER DESTRUCTOR CO.

205-S East 42nd St. **New York 17, N. Y.**

Representatives in Principal Cities

Leaders

in the design of

industrial waste problems

INFILCO's experience in solving industrial waste disposal problems through the application of activated sludge equipment is available to you today, at no obligation. Write for details.

BIOLOGICAL TREATMENT OF INDUSTRIAL WASTES with activated sludge is not new with INFILCO, an organization long considered a leader in the development of activated sludge processes and equipment.

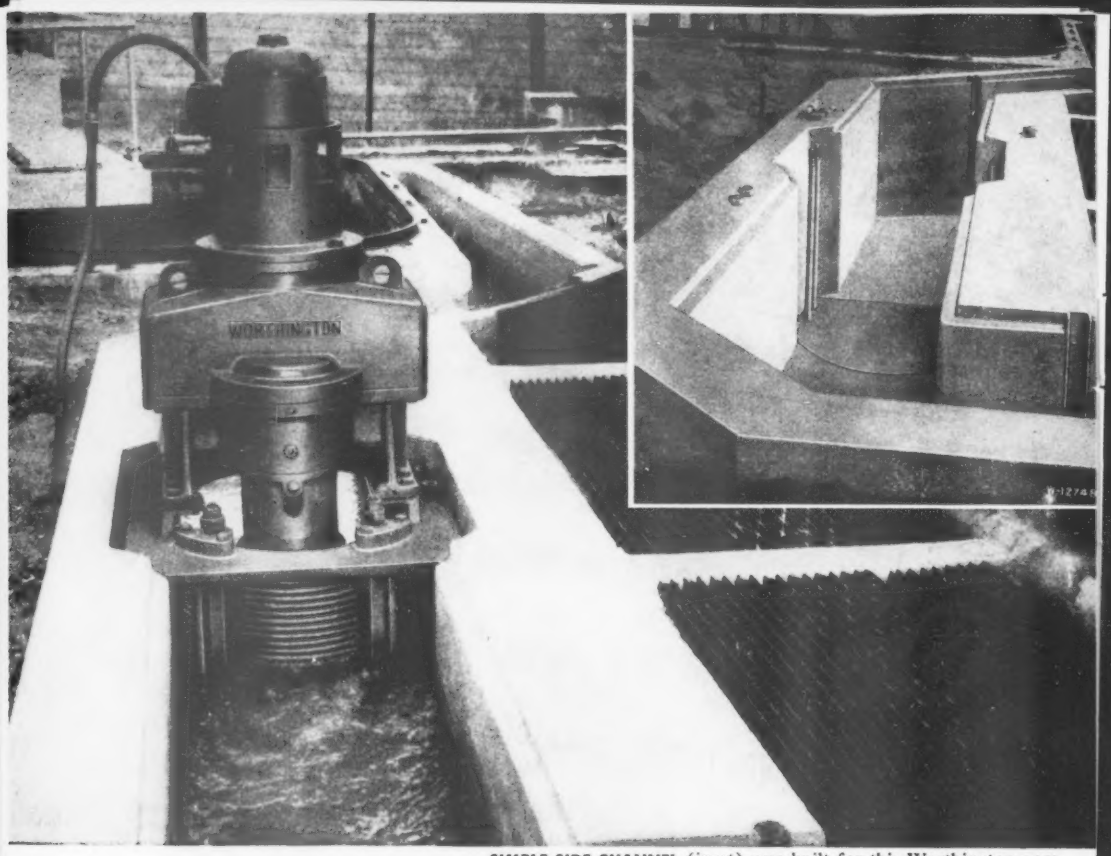
Many installations treating vegetable canning, refinery, pulp, paper and a variety of other organic wastes, are in successful operation because INFILCO pioneered methods and equipment to adapt activated sludge treatment to the needs of industry's ever-increasing waste problem.

INFILCO

INFILCO INC. | *Tucson, Arizona*

Plants in Chicago and Joliet, Illinois

FIELD OFFICES IN 35 PRINCIPAL CITIES IN THE U.S., CANADA AND MEXICO



SIMPLE SIDE CHANNEL (inset) was built for this Worthington comminutor at Klamath Falls, Oregon, because Mr. E. A. Thomas, the City Engineer, wanted to use the existing channel as a by-pass.

Low installation cost swings Klamath Falls to Worthington

Since the Worthington comminutor is designed so that raw sewage flows straight through its screen, it's easily installed in a straight rectangular sewage channel.

Result? Expensive masonry work is not needed, which makes for simplified, low-cost installation.

This was an important factor in the selection of a Worthington 25C6 comminutor as part of recent improvements at the Klamath Falls, Oregon, Sewage Treatment Plant.

This comminutor, installed downstream from a grit chamber and upstream from a clarifier, was lifted directly from its packing crate and set right in the channel in a minimum of time.

Easy-to-remove cutter racks for occasional sharpening and the built-in flood protection provided by a mercury seal are other advantages of the Worthington comminutor.

Get all the facts and figures on the rugged Worthington comminutor. Check with your nearest Worthington district office. Or write today for new engineering manual on comminutors, W-317-B17. Worthington Corporation, Public Works Division, Harrison, N.J.

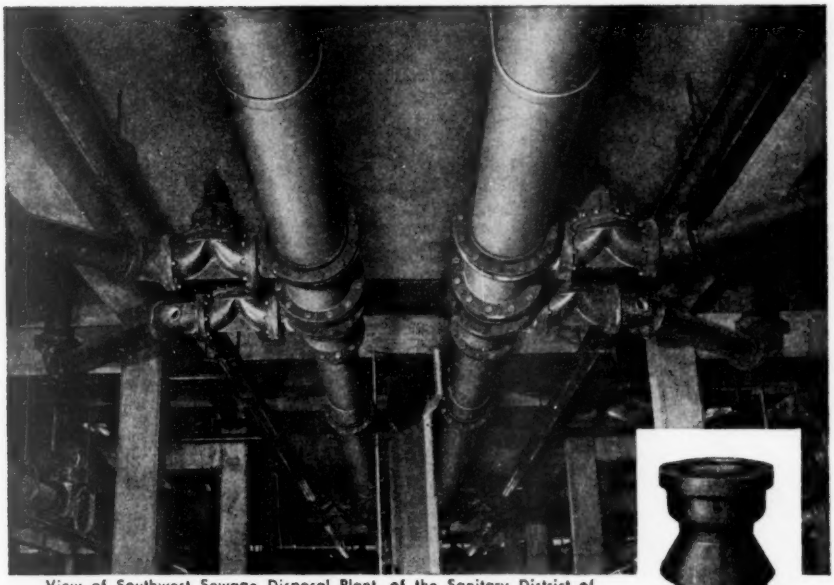
W.4.5

SEE the Worthington Corporation Exhibit in New York City. A lively, informative display of product developments for industry, business and the home. Park Avenue and 41st Street.

WORTHINGTON

ALL MAJOR PUBLIC WORKS EQUIPMENT UNDER ONE RESPONSIBILITY

Water Works Pumps • Sewage Pumps • Comminutors • Vertical Turbine Pumps • Vacuum Pump



View of Southwest Sewage Disposal Plant, of the Sanitary District of Chicago, Stickney, Illinois . . where Clow Cast Iron Pipe was furnished to meet exact requirements.

Clow cast iron pipe, fittings, valves and specials for sewage plant replacements or new installations

• James B. Clow & Sons with their many years of experience as manufacturers of Cast Iron Pipe and Special Castings for Filtration and Sewage Disposal Plants know the difficult piping problems that continually face the sanitary engineer. Clow shops are completely equipped with the latest machinery. Clow's skilled workmen will produce pipe and specials to your exact specifications. Pipe can be furnished flange and flange, flange and bell, flange and plain end or with mechanical joint and plain end—in sizes 3 through 24 inches in laying lengths up to 18 feet.

CLOW (Threaded) Cast Iron Pipe

Clow also manufactures (threaded) Cast Iron Pipe in steel pipe sizes 3 through 10 inches which has the same outside diameter as common steel pipe. This pipe can be cut, threaded and fitted on the job with ordinary tools of the piping trade.

1878 —This is our Seventy-Fifth year— 1953

JAMES B. CLOW & SONS ☆

201-299 North Talman Avenue • Chicago 80, Illinois

and their National Cast Iron Pipe Division, Birmingham, Ala.
Subsidiaries:
Eddy Valve Co., Waterford, N. Y.
Iowa Valve Co., Oskaloosa, Iowa

Interchangeable Parts

Keep Costs Down

WITH
CHAPMAN
Standard
SLUICE GATES

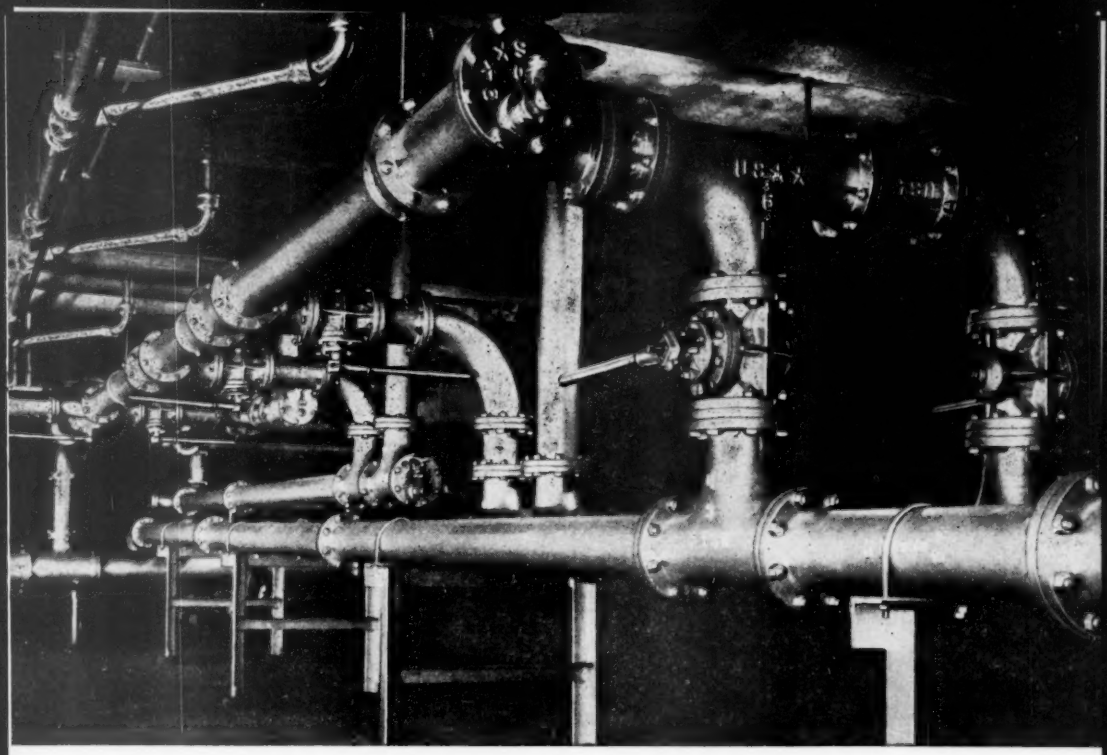
There's no need for match-marking on a Chapman *Standard* Sluice Gate installation. Component parts are absolutely interchangeable, made to fit perfectly, every time, without alterations.

That means installation is always fast and simple. And replacement parts, if necessary, fall right into place without fitting.

Chapman Standard Sluice Gates are available in a wide range of sizes and designs to meet the needs of almost any installation. Many special designs are also available at slight extra charge. All with any type of operating control you want — manual, hydraulic, or electric motor.

Write now for Catalog 25.

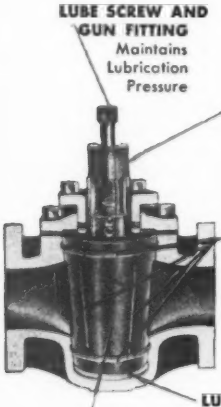
THE CHAPMAN VALVE MFG. CO.
INDIAN ORCHARD, MASSACHUSETTS



Gummy Sludge Won't Foul These Valves

Pressure Lubricated ROCKWELL-Nordstrom VALVES

Are A Natural For Sludge Lines

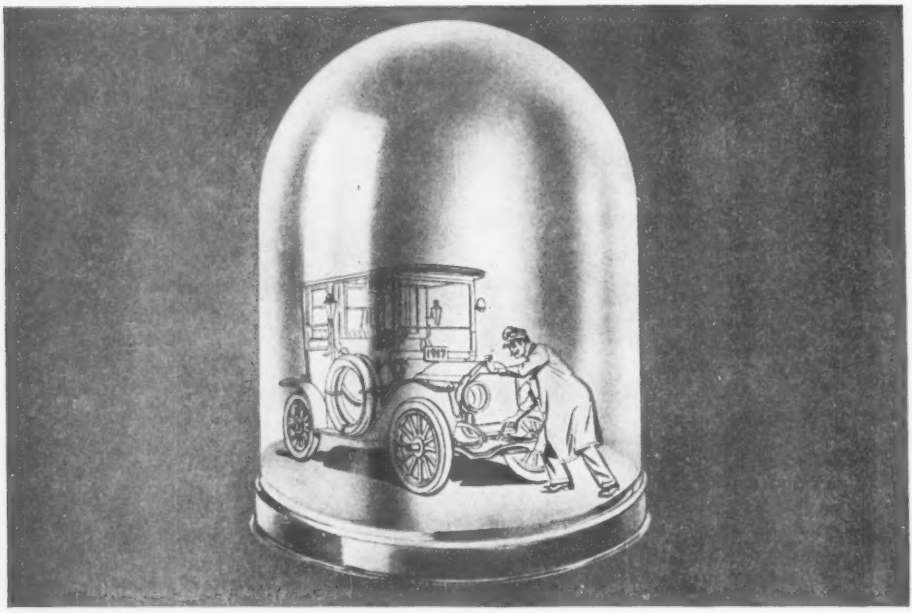

LUBE SCREW AND GUN FITTING
Maintains Lubrication Pressure
STEM
One-Quarter Turn To Open Or Close Valve
LUBE CHANNELS
A Perfect Seal . . . Cut-Offs Prevent Leakage Into Line
LUBE CHAMBER
Jacks Up Plug For Easy Operation . . . Eliminates Stuck Valves
TAPERED PLUG
Maximum Strength . . . Perfect Seating . . . Seat Never Exposed

Sludge lines are the nemesis of ordinary valves. Gummy line materials pack into cavities and before long the line's out of operation for valve replacement.

Because Rockwell-Nordstrom valves are pressure lubricated and operate on the rotary plug principle, there are no internal cavities to pack with sludge solids, jamming the seat. Also, vital working surfaces are fully protected by the lubricant against corrosion. The valve seat is never exposed, and line material is instantly sheared off with a knifelike action as the plug rotates past the valve throat. Galled or frozen valves are eliminated by simply turning the lube screw which hydraulically jacks the plug and frees it for instant, one-quarter turn operation.

In the toughest service, Rockwell-Nordstrom valves will give you performance more dependable, longer lasting, more economical than any other valve you've ever used. They're available in a full range of sizes up to 34 in., and in various steel and special alloy patterns. *Write today for complete information.* Rockwell Manufacturing Company, Pittsburgh 8, Pa. *Canadian Valve Licensee:* Peacock Brothers Limited.

ROCKWELL-Nordstrom VALVES *Lubricant-Sealed for Positive Shut-Off*



how much does it cost . . . to "crank" an old style chlorinator?

The automobile self-type starter isn't news any more — nobody ever cranks a car these days. "Cranking" an old-style chlorinator is equally out-dated.

The F&P mechanical, instrument-type chlorinator is sweeping the country, sales mount month by month. Why? Because municipality after municipality, consulting engineer after consulting engineer, reports the same facts: F&P chlorinators are lower in first cost, are easier to handle, because they are so simple in design, so light in weight, so modern in construction. More important, however, it is always stressed that F&P chlorinators require practically no maintenance, practically no spare parts.

We claim that if you are operating a chlorinator that has a bell jar on it *you need a new chlorinator*. You are "cranking" an old, costly, inefficient chlorinator. Everybody knows that dry chlorine is not corrosive—but that as soon as you put the chlorine in contact with water or water vapor it becomes corrosive. That's what the water tray types of chlorinators do—put dry, non-corrosive chlorine in contact with water and make corrosive vapor out of it. It's not engineering sense and the way to avoid it—and the resulting expensive maintenance — is to get F&P *mechanical, instrument type* chlorinators.

Don't refrain from writing us because you don't need additional chlorinating capacity right now. Moreover—if it is time for a major overhaul or a rebuilding of your bell jar chlorinator, let us quote you for doing this work. We will give you what you may not have gotten previously—a firm price for doing the job before we start on it. The price will be a reasonable one, but we'll also quote you a price for replacing the chlorinator and if you want to spread the cost of the new one by time payments or if you want a lease arrangement, you can have it. Chances are you cannot justify further overhaul or further rebuilding—even at our *fair* price for doing the work.

FP

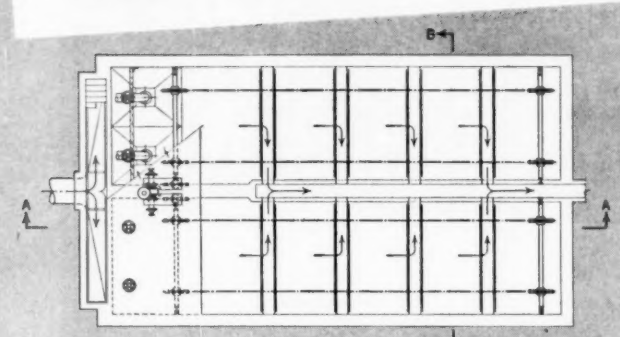
complete process instrumentation

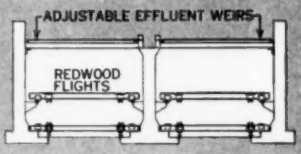
FISCHER & PORTER CO.

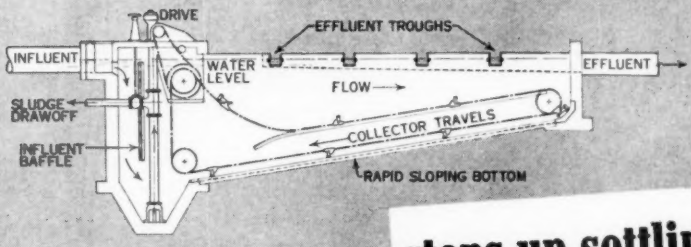
1204 Fischer Road, Hatboro, Penna.

18 YEARS EXPERIENCE SUCCESSFULLY MANUFACTURING CHLORINE FLOW METERING EQUIPMENT

New UNIFLOW settling tank







Link-Belt's new UNIFLOW settling tank can be utilized for economical removal of solids from water, sewage or industrial liquids. Uniflow tanks are equipped with Link-Belt Straight-line Sludge Collectors which will remove sludge from the tank floor and scum from the surface.

steps up settling efficiencies . . cuts construction costs

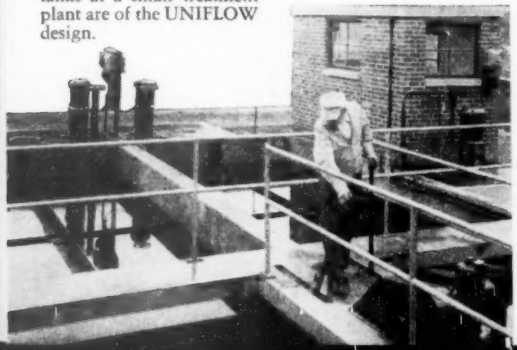
LINK-BELT development offers new economies for water, sewage and industrial liquids treatment

WITH its rapidly sloping bottom and multiple effluent weirs, Link-Belt's new UNIFLOW settling tank represents a big design advance. These, combined with the decreasing cross sectional area, provide *uniform velocity throughout the tank.*

Result: Better settling conditions . . . low overflow rate . . . uniform discharge from a large area of the tank surface. In fact, on one New England experimental installation, UNIFLOW gave practically the same efficiency in B.O.D. and suspended solids removal as a conventional tank with one-third more volume.

The new economies possible with UNIFLOW are typical of the development work constantly under way at Link-Belt. If you have a water, sewage or industrial waste problem, our engineers will work with your engineers, chemists and consultants. They'll help you get the finest in modern treatment equipment.

Primary and final settling tanks at a small treatment plant are of the UNIFLOW design.

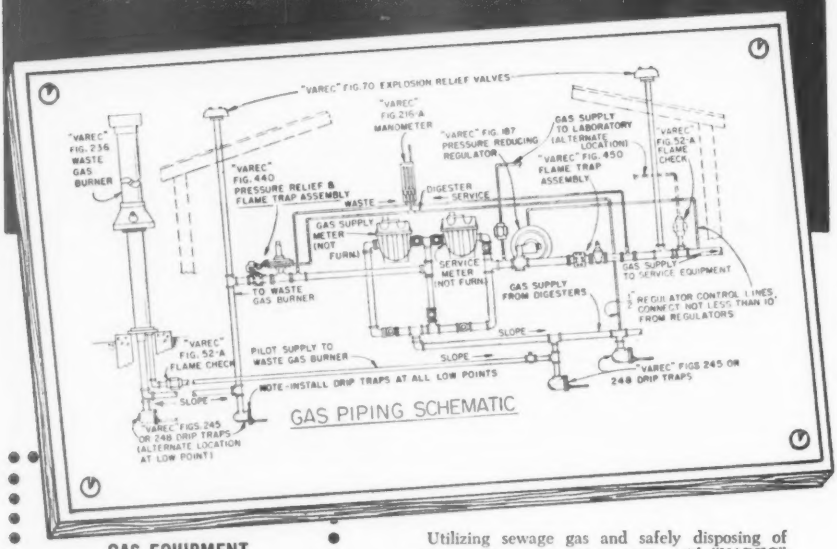


LINK-BELT COMPANY: Executive Offices, 307 N. Michigan Ave., Chicago 1. To Serve Industry There Are Link-Belt Plants and Sales Offices in All Principal Cities. Export Office, New York 7; Canada, Scarboro (Toronto 13); Australia, Marrickville, N.S.W.; South Africa, Springs. Representatives Throughout the World. 13.493

LINK-BELT

SANITARY ENGINEERING EQUIPMENT

"VAREC" figures in *Your* SEWAGE TREATMENT PLANT DESIGN for SAFETY and GAS CONTROL


"VAREC" FIG. 70 EXPLOSION RELIEF VALVES
"VAREC" FIG. 236 WASTE GAS BURNER
"VAREC" FIG. 216-A MANOMETER
"VAREC" FIG. 187 PRESSURE REDUCING REGULATOR
GAS SUPPLY TO LABORATORY (ALTERNATE LOCATION)
"VAREC" FIG. 450 FLAME TRAP ASSEMBLY
"VAREC" FIG. 52-A FLAME CHECK
"VAREC" FIG. 440 PRESSURE RELIEF & FLAME TRAP ASSEMBLY
WASTE
DIGESTER SERVICE
GAS SUPPLY METER (NOT FURN.)
SERVICE METER (NOT FURN.)
GAS SUPPLY FROM DIGESTERS
GAS SUPPLY TO SERVICE EQUIPMENT
REGULATOR CONTROL LINES CONNECT NOT LESS THAN 10' FROM REGULATORS
TO WASTE GAS BURNER
"VAREC" FIG. 52-A FLAME CHECK
PILOT SUPPLY TO WASTE GAS BURNER
SLOPE
NOTE - INSTALL DRIP TRAPS AT ALL LOW POINTS
"VAREC" FIGS 245 OR 248 DRIP TRAPS
"VAREC" FIGS. 245 OR 248 DRIP TRAPS (ALTERNATE LOCATION AT LOW POINT)
GAS PIPING SCHEMATIC

GAS EQUIPMENT SPECIFICATIONS

PRESSURE RELIEF AND FLAME TRAP ASSEMBLY
"VAREC" Fig. No. 440

FLAME TRAP ASSEMBLY
"VAREC" Fig. No. 450

FLAME CHECK
"VAREC" Fig. No. 52A

EXPLOSION RELIEF VALVES
"VAREC" Fig. No. 70-1

WASTE GAS BURNER
"VAREC" Fig. No. 236

DRIP TRAPS
"VAREC" Fig. No. 245 (automatic)
"VAREC" Fig. No. 248 (hand operated)

MANOMETERS
"VAREC" Fig. No. 216A

"Varec"

Utilizing sewage gas and safely disposing of excess gas is an automatic operation with "VAREC" Equipment incorporated into your sewage plant design. With this equipment, accurate gas pressures are maintained in all service lines. As soon as the digesters make more gas than required for service, the pressure relief valve to the waste gas burner opens to permit safe burning of the excess.

Flame flashback to valuable equipment is prevented with "VAREC" Flame Traps and Flame Checks. The flame arresting element of the Flame Trap is designed to eliminate flame propagation of even more inflammable gases than encountered in sewage service. This element is the same as that used in "VAREC" Flame Arresters listed by the UNDERWRITERS' LABORATORIES for petroleum product storage.

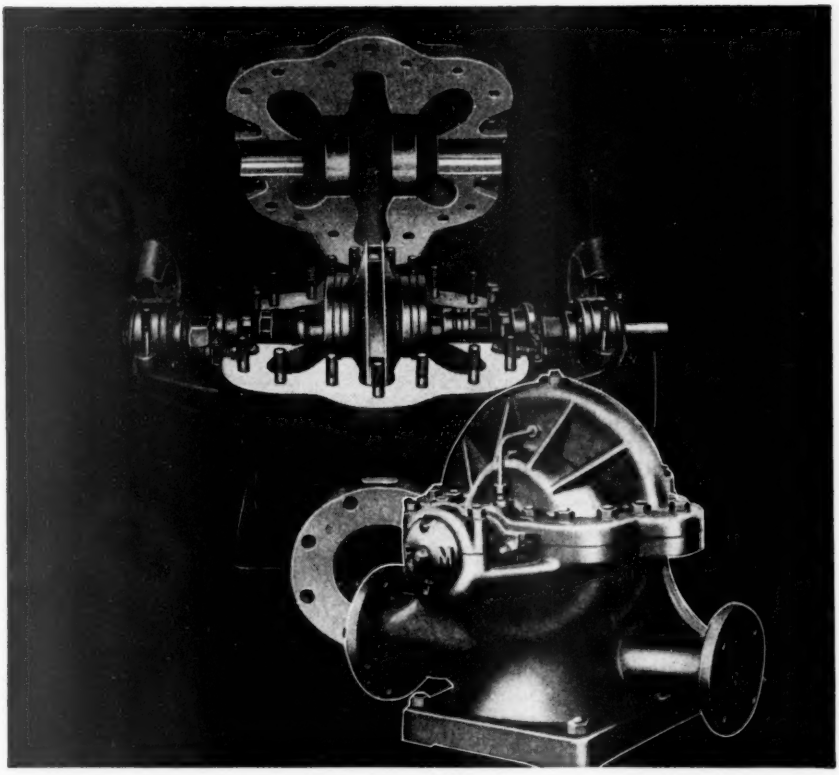
Emergency explosion relief is accomplished with "VAREC" Explosion Relief Valves. These valves should be installed outside of any buildings.

An enlarged engineering drawing of the above gas piping detail will be sent upon request. If you design sewage treatment plants, write today.

THE VAPOR RECOVERY SYSTEMS CO.
COMPTON, CALIFORNIA, U. S. A.
Cable Address: VAREC COMPTON USA (All Codes)

New York, N.Y. • Boston, Mass. • Pittsburgh, Pa. • Chicago, Ill. • Detroit, Mich. • St. Louis, Mo. • Houston, Texas • Tulsa, Okla. • San Francisco, Calif. • Seattle, Wash. • Minneapolis, Minn. • Honolulu, Hawaii

Available from authorized Sewage Equipment agents throughout United States and Canada



out of the mouth of a pump...

Suppose a pump could "spill its works" . . . tell you how it was made . . . speak of the design, material, workmanship that went into its being . . . then you could know . . . and buy with confidence.

Because after all, pumps do look alike. How, then, to tell which make is best for you. *Reputation* is one way, *performance* another.

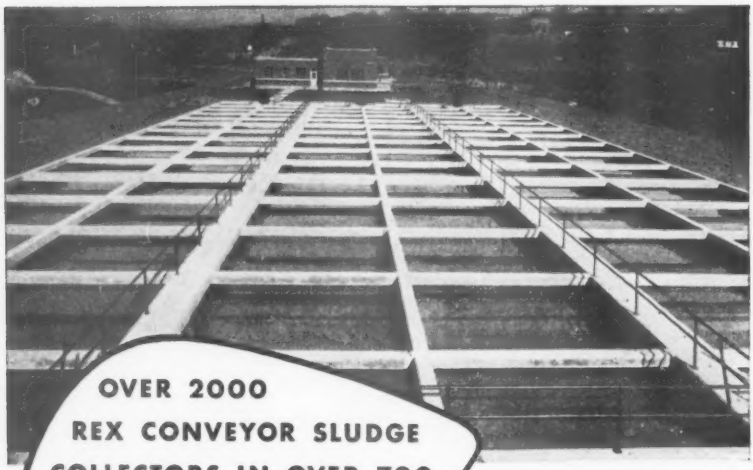
And, on both counts, Fairbanks-Morse pumps stand out. Don't take our word for it. Check with Fairbanks-Morse users. We'll stand by their verdict. For Fairbanks-Morse has only one standard . . . *quality* . . . the quality that means dependability, service, low maintenance, all those important points that you want in the pumps you buy.

To get these advantages in your pumps, rely on the world's largest manufacturer of a complete pump line. See your nearest Fairbanks-Morse Branch, pump dealer, or write Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago 5, Illinois.

FAIRBANKS-MORSE

a name worth remembering when you want the best

PUMPS • SCALES • DIESEL LOCOMOTIVES AND ENGINES • ELECTRICAL MACHINERY
RAIL CARS • HOME WATER SERVICE EQUIPMENT • FARM MACHINERY • MAGNETOS



OVER 2000
REX CONVEYOR SLUDGE
COLLECTORS IN OVER 700
CITIES AND INDUSTRIES!

WHAT BETTER PROOF of Rex superiority?

YES over 700 cities and industries rely on Rex® Conveyor Sludge Collectors for efficient, dependable and economical operation. They are applicable for all types of sludge handling or surface skimming conditions in either sewage, water or industrial waste treatment application.

Here are some of the time-proven features of Rex Sludge Collectors:

★ ***Balanced Equipment Design***—design proportionate throughout.

★ ***Rex Z-Metal Chain and attachments***—resist corrosion and wear.

★ ***Self-Aligning Bearings***—compensate for tank irregularities.

★ ***Centralized, Hardened Wearing Shoes***—eliminate splitting strains on wooden scraper flights.

★ ***Offset Split Drive Sprockets***—eliminate cantilevered brackets.

★ ***Double Life Sprockets***—chain engages every other sprocket tooth.

★ ***Drive Unit***—compact, totally enclosed. Shear pin protection.

★ ***Sub-Assemblies***—shop assembly of drive units and shaft assemblies assure proper alignment and fit.

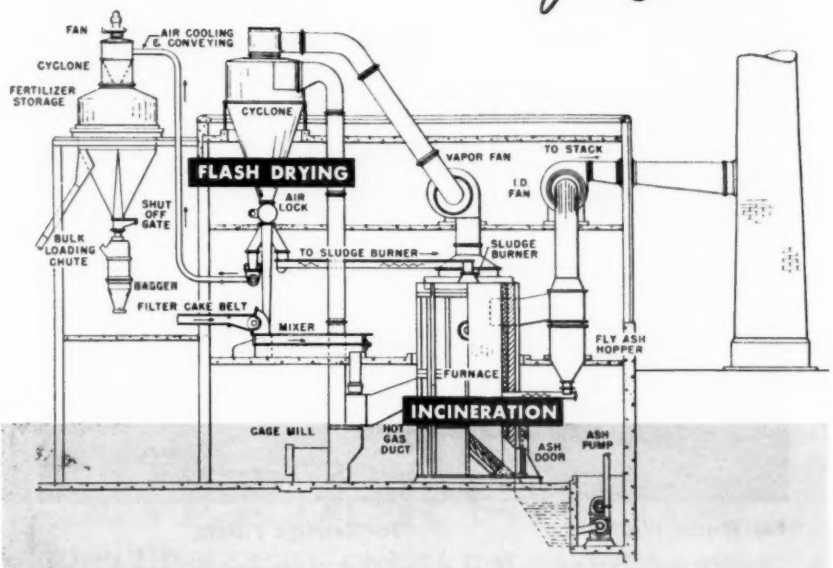
MAKE SURE YOU WILL BE THE NEXT ONE to profit from Rex design and Rex quality. Get all the facts on Rex Conveyor Sludge Collectors. Call your nearest Rex Sanitation Engineer or write for Bulletin 47-9. Chain Belt Company, 4606 W. Greenfield Ave., Milwaukee 1, Wisconsin.

CHAIN BELT REX COMPANY

Chain Belt COMPANY OF *MILWAUKEE*

Atlanta • Baltimore • Birmingham • Boston • Buffalo • Chicago • Cincinnati • Cleveland
Dallas • Denver • Detroit • El Paso • Houston • Indianapolis • Jacksonville • Kansas City
Los Angeles • Louisville • Midland, Texas • Milwaukee • Minneapolis • New York
Philadelphia • Pittsburgh • Portland, Ore. • West Springfield, Mass. • St. Louis
Salt Lake City • San Francisco • Seattle • Tulsa • Worcester
Distributors in Principal Cities in the United States and abroad
Export offices: 4800 W. Mitchell Street, Milwaukee, Wisconsin; and 19 Rector St., New York City

Which **SLUDGE DISPOSAL SYSTEM** *is best for you?*



Only the C-E Raymond System of Flash Drying & Incineration offers the proved, practical flexibility which permits *either* flash drying sewage sludge to a marketable fertilizer . . . or incinerating it to a sterile ash—in any proportion and under complete control. In either case, too, high temperature deodorization of stack gases may be included if you wish.

This flexibility of the C-E Raymond System is an important reason why it is the most widely used heat method of sewage sludge disposal. In fact, the total daily capacity of C-E Raymond Systems installed, under construction or on order is *nearly 50% more than all other heat methods combined.*

Furthermore, the C-E Raymond System has been proved in service in communities of every size—ranging in equivalent population from 6,000 to 3,600,000—and located in every section of the country, coast to coast.

So, whatever your particular requirements, look to the leader for help in selecting the proper equipment. The services of a qualified engineer are freely available to you or your consultants. B-755A

COMBUSTION ENGINEERING

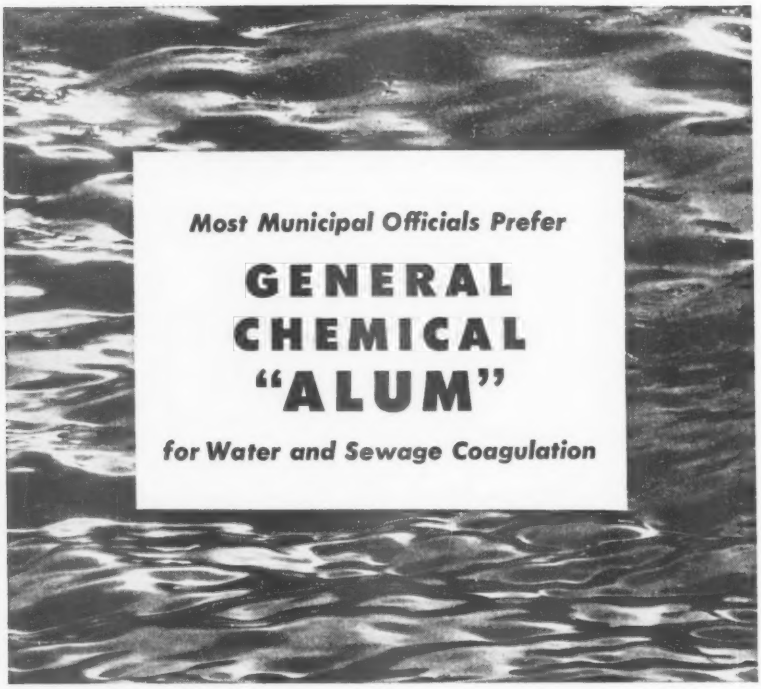
C-E

RAYMOND DIVISION

1315 North Branch Street, Chicago 22, Illinois

Eastern Office: 200 Madison Ave., New York 16, N. Y. Western Office: 510 W. Sixth St., Los Angeles 14, Calif.

ALSO FLASH DRYING AND INCINERATION SYSTEMS FOR INDUSTRIAL WASTE DISPOSAL



For Water Works

1. Produces crystal-clear water
2. Gives effective floc formation over wide pH and alkalinity conditions
3. Insures settling of fine turbidity resulting in longer filter runs
4. Helps reduce tastes and odors
5. Removes organic color from water
6. Has no chlorine demand, because the aluminum ion has no reduced state
7. Stores well and remains free-flowing for uniform feeding

For Sewage Plants

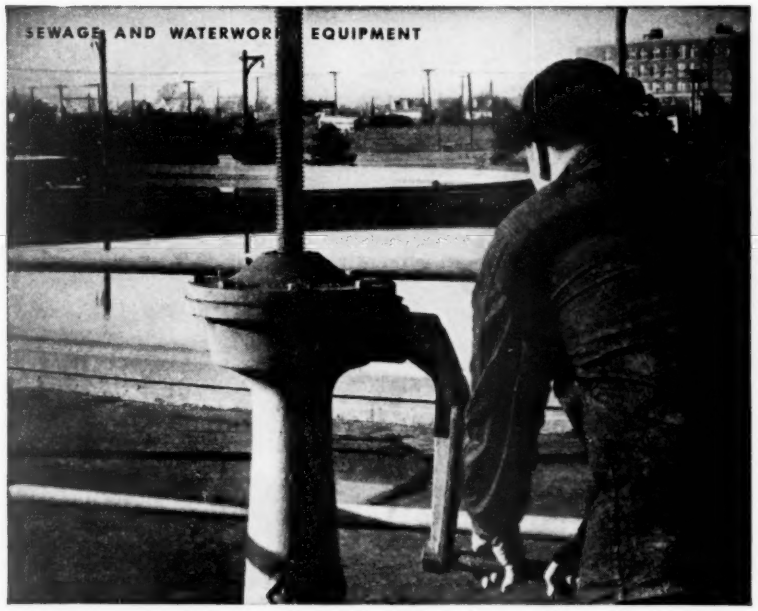
1. Clean and easy to handle
2. Dry feeds well or dissolves readily for solution feeding
3. Simple application; requires only low cost feeding apparatus and minimum attention
4. Makes clear, low-color effluents possible
5. Flocs effectively over wide pH and alkalinity conditions
6. Helps sludge digest and dry readily with minimum of odor
7. Reduces chlorine consumption in the effluent

Always Readily Available from Coast-to-Coast Distribution Points

GENERAL CHEMICAL DIVISION
ALLIED CHEMICAL & DYE CORPORATION
40 Rector Street, New York 6, N. Y.

Offices: Albany • Atlanta • Baltimore • Birmingham • Boston
Bridgeport • Buffalo • Charlotte • Chicago • Cleveland • Denver
Detroit • Greenville (Miss.) • Houston • Jacksonville • Kalamazoo
Los Angeles • Minneapolis • New York • Philadelphia • Pittsburgh
Providence • San Francisco • Seattle • St. Louis • Yakima (Wash.)
In Wisconsin: General Chemical Company, Inc., Milwaukee
In Canada: The Nichols Chemical Company, Limited • Montreal • Toronto • Vancouver

GC
Allied Chemical



EVERDUR STEMS:

TURN THEM EASILY—ONCE A DAY OR ONCE A YEAR. THEY RESIST CORROSION.

Rust and efficiency—like oil and water—don't mix. In gate and valve stems rust costs money. You avoid this by specifying stems made of Everdur*—*strong, rustproof and corrosion-resistant.*

Everdur Copper-Silicon Alloys have long been fabricated into lightweight sewage and waterworks structures. Gates, screens, guides and bolts, weirs, float chambers, troughs, manhole steps and electrical conduit—all gain *extra* protection when made of Everdur.

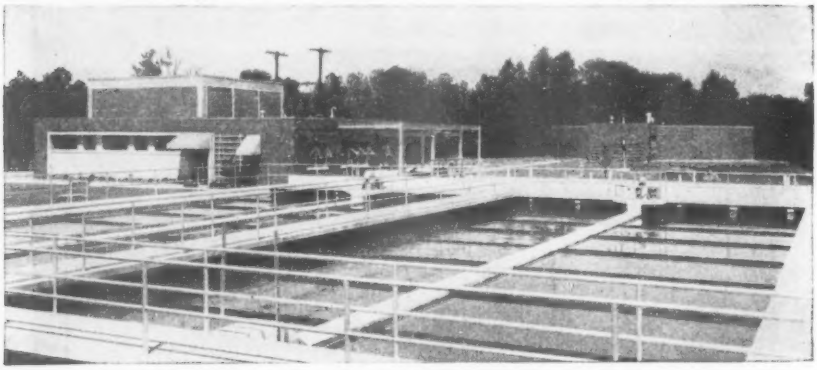
Depending on the type or composition, you can work Everdur Alloys hot or cold, and readily form, forge, weld and machine them. They are available in plates, sheets, rods, tubes, electrical conduit and casting ingots.

Write for free booklet, "Everdur Copper-Silicon Alloys for Sewage and Waterworks Equipment." For practical advice on selecting the correct material for your equipment, consult our Technical Department. Their services are freely available. *The American Brass Company, Waterbury 20, Connecticut. In Canada: Anaconda American Brass Ltd., New Toronto, Ont.*

*Reg. U. S. Pat. Off. 53139A

EVERDUR
ANACONDA®
COPPER-SILICON ALLOYS
STRONG • WELDABLE • WORKABLE
CORROSION-RESISTANT

"East Side Plant"—first of 2 new sewage treatment plants for Evansville, Indiana



Evansville joins Ohio River clean-up program

TWO-PLANT, 28 MGD PROJECT INCLUDES PFT "CONTROLLED DIGESTION"

At Evansville, Indiana, the first of two proposed primary treatment plants is completed . . . another stride forward in the 8-state Ohio River Valley clean-up program! Called the "East Side Plant" the new 6 MGD plant adopted PFT equipment for modern "controlled digestion".

The new 75′ digester is equipped with a *PFT Floating Cover* for simplified operation, positive scum submergence and safe utilization of gas. The digester is also provided with a *PFT Supernatant Liquor Selector* for automatic, continuous withdrawal of the best digester liquor. A *PFT Gauge, Sight Glass and Sampler* unit enables operator to keep close control of supernatant.

An important feature of Evansville's "controlled digestion" is the *PFT Digester Heater & Heat Exchanger*, an external heater with a capacity of 750,000 B.t.u. per hour. Fired by either gas *or* oil, it utilizes all sludge gas produced, switching to oil only when necessary

In the control building attached to the digester, a *PFT Cover Position Indicator* records the digester liquid level at a glance. *PFT Gas Safety Equipment* in the building includes flame cells, flame traps, pressure relief with flame trap, gas pressure gauge and a waste gas burner.

New 75′ Digester with PFT Floating Cover

Contracts have recently been let for the "West Side Plant", a 22 MGD plant designed to serve a population equivalent of 212,000. Specifications for "West Side" call for the following PFT equipment: four 75′ Floating Covers; three 8″ Rotary Sludge Withdrawal Valves; two Heater & Heat Exchanger units; four Cover Position Indicators; four Supernatant Liquor Selectors; four Supernatant Gauge, Sight Glass & Sampler units; various items of Gas Safety Equipment.

Design of plant by / Consoer, Townsend & Associates, Chicago, Illinois.

P.F.T.

waste treatment equipment exclusively since 1893

PACIFIC FLUSH TANK CO.

4241 Ravenswood Avenue
Chicago 13, Illinois

NEW YORK · LOS ANGELES · SAN FRANCISCO · CHARLOTTE, N. C · JACKSONVILLE · DENVER

SEWAGE AND INDUSTRIAL WASTES

Journal of the Federation of Sewage and Industrial Wastes Associations

Volume 26 **October, 1954** **Number 10**

Contents

Sewage Works

Physical Behavior of Synthetic Detergents. I. Preliminary Studies on Frothing and Oxygen Transfer. By William O. Lynch and Clair N. Sawyer 1193

Plant-Scale Studies of Thermophilic Digestion at Los Angeles. By William F. Garber 1202

A Simplified Technic for Atmospheric H_2S Studies. By Garson Chanin, John R. Elwood, and Edward H. Chow 1217

Industrial Wastes

Oxidation of Enzyme Desize and Starch Rinse Textile Wastes. By Nelson L. Nemerow 1231

Pilot-Plant Studies of Refinery Wastes Treatment on Trickling Filters. By Gordon E. Mau 1236

Small-Scale Laboratory Units for Continuously-Fed Biological Treatment Experiments. I. Aeration Units for Activated Sludge. By Richard Hatfield and E. R. Strong 1255

Stream Pollution

Industrial Pollution of International Boundary Waters Along the Niagara Frontier. By Hayse H. Black and Earl Devendorf 1259

Discussion by Lyman Cox 1285

Research Activities

Public Health Service Research Grants in Environmental Health. By Irving Gerring 1286

The Operator's Corner

Screenings and Grit Complicate Starting Operations at Nut Island Sewage Treatment Plant. By Joseph B. Hanlon 1290

Pump Packing and Digester Cleaning Hints. By J. E. Meers 1302

Tips and Quips 1303

Reviews and Abstracts 1305

Book Reviews 1307

Proceedings of Member Associations

New England Sewage and Industrial Wastes Association 414a

W. H. Wisely, *Editor*, 325 Illinois Building, Champaign, Illinois

Herbert P. Orland, *Associate Editor* Dr. F. W. Mohlman, *Advisory Editor*

Donald P. Schiesswohl, *Assistant Editor* Mrs. A. H. Skates, *Editorial Assistant*

Copyright, 1954, by the Federation of Sewage and Industrial Wastes Associations. Reprints from this publication may be made only if permission of the Editor is secured and on condition that the full title of the article, name of the author and complete reference are given. The Federation assumes no responsibility for opinions or statements of facts expressed in papers or discussions published in this *Journal*.

12 years of operation at a repair parts cost of

Only $3.55 per year...

Typical Proof that

DORR CLARIFIER

Maintenance Cost

is LOW!

That's right, the 3 Dorr Clarifiers at the Jonesboro, Arkansas Biofiltration plant have been in operation for 12 years . . . and the total repair parts cost has been only $3.55 per unit per year. Unusual? No . . . it's typical of reports received from large cities and small towns alike — reports based on factual records. And what's more . . . it's the kind of low maintenance cost you can expect when you use Dorr units. Repair costs are one of the primary factors upon which Clarifier excellence should be judged. Are you getting the best? We'd like to tell you how Dorr Clarifiers stack up on performance too. Ask a Dorr Engineer for the facts.

12 YEAR REPAIR PARTS COST RECORD AT JONESBORO, ARKANSAS

Number of Units	Size and Type of Clarifiers	Years of Operation	Repair Parts Cost			Repairs as % of	
			Total	Per Unit	Per Unit Per Year	Original Cost	Original Cost Per Year
2 1	35 ft. Type SU 45 ft. Type SU	12	$127.55	$42.52	$3.55	1.74	0.145

Better tools TODAY to meet tomorrow's demand.

DORR

WORLD-WIDE RESEARCH • ENGINEERING • EQUIPMENT

FIFTY YEARS 1904–1954

THE DORR COMPANY • ENGINEERS • STAMFORD, CONN.

Offices, Associated Companies or Representatives in principal cities of the world.

Sewage Works

PHYSICAL BEHAVIOR OF SYNTHETIC DETERGENTS

I. Preliminary Studies on Frothing and Oxygen Transfer *

By William O. Lynch † and Clair N. Sawyer

Department of Civil and Sanitary Engineering, Massachusetts Institute of Technology, Cambridge, Mass.

In the years since the close of World War II, American households and industries have been turning increasingly to the use of so-called synthetic detergents as superior replacements for "natural" soaps. At the same time, those concerned with the treatment and disposal of sewage and industrial wastes and with the treatment and purification of water supplies have become increasingly concerned with a variety of new problems attributed to this change in America's washing habits.

Phenomenal frothing in activated sludge plants and receiving waters, reduction of gas production in sludge digestion units, coagulation and settling difficulties at water plants treating polluted waters, and increased air requirements at activated sludge plants (despite diminishing 5-day B.O.D. values) have been blamed on synthetic detergents (1)(2)(3)(4)(5). Synthetic detergents, or syndets, have not been without their champions, however, especially in denying their responsibility in the most spectacular of these problems—frothing (6)(7). Regardless of such denials, however, many sewage treatment plant operators are certain that domestic sewage has changed markedly in character during the decade 1944–1954, and syndets seem the only logical explanation.

This paper is concerned with certain preliminary studies on frothing tendency and oxygen transfer in connection with a program of research into the fundamental physical behavior of synthetic detergents, especially as related to sanitary engineering processes. While these were preliminary, or exploratory studies, aimed at delineating areas for more thorough research, it is believed that they contain information of considerable interest to the sanitary engineering profession, provided care is exercised in translation of the results into terms of sewage treatment processes.

Method of Study

The apparatus used in these studies consisted of a lucite pipe or column, 4 in. in internal diameter and 9 ft. high, with a small, porous, air-diffusion bulb inserted near the bottom. Sampling taps and a thermometer were located in the column, and a nozzle-type flow meter with mercury manometer afforded control of the air supplied to the diffuser.

In operation, the column was filled to a depth of 6.7 ft. above the diffuser. Cambridge, Mass., tap water (total solids, 110 to 125 p.p.m.; hardness, 65 to 80 p.p.m.; alkalinity, 30 to 35 p.p.m.; pH, 7.2 to 8.5) was used in all these studies. Nitrogen was first passed

* Presented at 25th Anniversary Meeting, New England Sewage and Industrial Wastes Assn.; Boston, Mass.; April 22–23, 1954.

† Present address: School of Civil Engineering, Cornell University, Ithaca, N. Y.

through the diffuser to strip the dissolved oxygen from the water. Syndet was next added, to give the desired concentration, and mixed with the water by the use of more nitrogen. Aeration was then begun, and samples for dissolved oxygen analysis were withdrawn at timed intervals. To eliminate as many variables as possible, all runs were made at approximately the same temperature (25° C.) and airflow rate (90 ml. per min.), and all samples were withdrawn from the same sampling tap and at the same intervals of elapsed time after the start of each run.

Sperry (2) estimated the concentration of syndets in Aurora, Ill., sewage to be 45 p.p.m. (as marketed); hence 50 p.p.m. was selected as a reasonable level at which to conduct most of these preliminary studies. The products studied were all purchased on the retail market and the concentrations used were all in terms of these brand name packaged products.

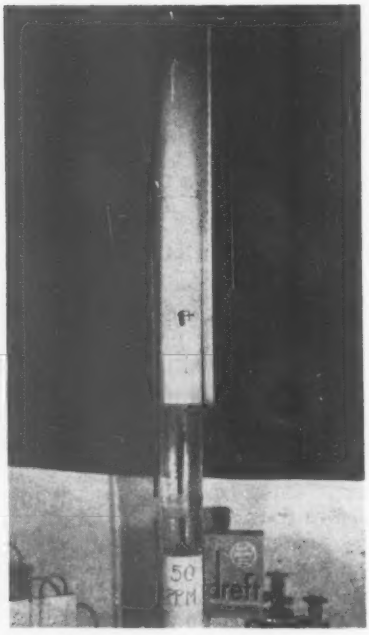


FIGURE 1.—Frothing characteristics of anionic retail syndet (50 p.p.m. Dreft) in Cambridge, Mass., tap water at 25° C.

FIGURE 2.—Frothing characteristics of anionic retail syndet (50 p.p.m. Tide) in Cambridge, Mass., tap water at 25° C.

In attempting to run dissolved oxygen analyses in the presence of syndets, it was discovered that many of the syndets interfered with the starch end point of the conventional Winkler technique. This difficulty was overcome by turning to an amperometric titration technique, thereby obviating the need for starch indicator. This technique involved addition of an excess of sodium thiosulfate to the "fixed" samples, then back titration of the excess amperometrically with standard iodine solution.

In instances where interference with oxygen absorption was noted, checks were made to see if any of the apparent interferences were due to an iodine demand of the syndet. Such iodine demands, where detected, were very small, but the data have been corrected for them nevertheless.

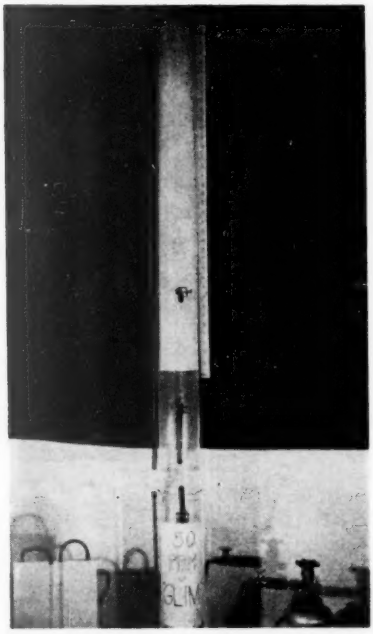


FIGURE 3.—Frothing characteristics of non-ionic retail syndet (50 p.p.m. Glim) in Cambridge, Mass., tap water at 25° C.

Surface tension and pH data were obtained on each of the mixtures studied, but since no correlation with frothing or oxygen transfer could be established, the data are not presented.

Frothing Tendency of Retail Syndets

A marked difference in the frothing characteristics of various retail synthetic detergents was found in these studies. Figures 1—5 illustrate the contrast between certain well-known brands, all photographs having been taken under comparable conditions of aeration time and syndet concentrations. The scale, in inches, alongside the aeration column shows the relative heights of the foam.

In view of the fact that Dreft (Figure 1), Tide (Figure 2), and Surf (Figure 5) are all classed as anionic detergents, it is interesting to note the extreme contrast between Tide, on the one hand, and Dreft and Surf, on the other. Tide frothed rather early in the run to the 1-in. height of weak froth shown, and maintained this level throughout the run, but Dreft and Surf continued to pile up a deeper and deeper "head" of rich froth throughout the aeration period. Of the other anionics studied, Vel, Breeze, and Cheer were similar to Dreft and Surf; Oxydol was similar to Tide; and Fab fell between the two extremes. Similarly, in the non-ionic class Glim (Figure 3) and Joy were rich foamers, whereas All (Figure 4) showed no frothing tendency whatsoever. These studies, therefore, showed no correlation between frothing and non-frothing *versus* anionic and non-ionic classifications.

An interesting test of frothing characteristics involved the use of a mixture of a sudsing and a non-sudsing detergent, (Figures 5, 6, and 7). Figure 5, as previously noted, shows the

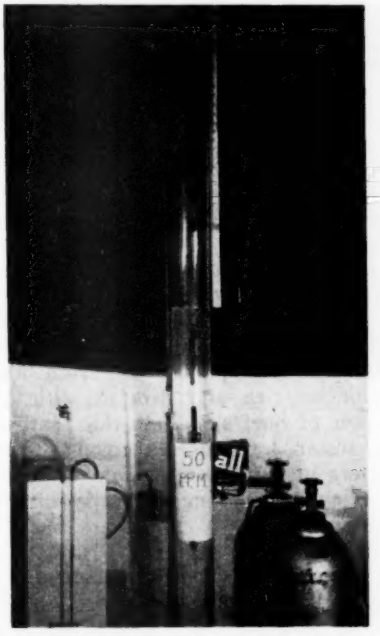


FIGURE 4.—Frothing characteristics of non-ionic retail syndet (50 p.p.m. All) in Cambridge, Mass., tap water at 25° C.

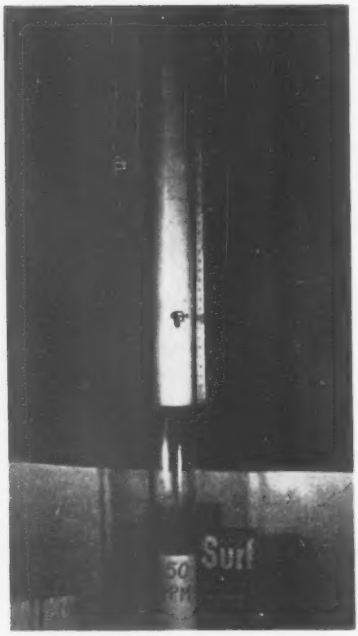


FIGURE 5.—Frothing characteristics of a sudsing-type syndet (Surf) at 50-p.p.m. concentration in Cambridge, Mass., tap water at 25° C.

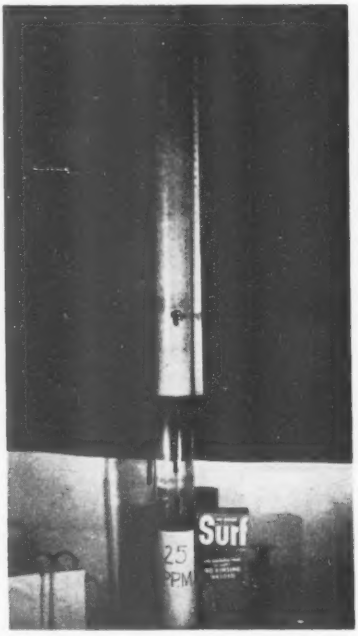


FIGURE 6.—Frothing characteristics of a sudsing-type syndet (Surf) at 25-p.p.m. concentration in Cambridge, Mass., tap water at 25° C.

frothing due to 50 p.p.m. of Surf. Figure 6 shows the froth due to 25 p.p.m. of Surf. Although of the same height as that caused by 50 p.p.m., the froth at 25 p.p.m. was weaker or less rich than at the higher concentration. When, however, non-sudsing All was mixed with Surf at a concentration of 25 p.p.m. each (Figure 7), so that the total syndet concentration was again 50 p.p.m., the froth was again as rich and firm as with 50 p.p.m. of Surf alone. In this particular instance, therefore, the non-sudsing detergent appeared capable of reinforcing the frothing properties of the sudsing one.

Influence of Retail Syndets on Oxygen Transfer

Figure 8 shows the results of studies on the rate of oxygenation. Dissolved oxygen content has been plotted *versus* time of aeration for a few of the syndets studied, as well as for Cambridge tap water alone. It is evident that under these test conditions the retail syndets studied varied considerably in their effect upon the rates of transfer of oxygen from the gaseous to the liquid phase.

The appearance of the curves in Figure 8 should suggest another very familiar curve to sanitary engineers, namely, that of first-stage B.O.D. *versus* time. This likeness is more than pure coincidence, for in reality the kinetics of both correspond to first-order (or unimolecular) reactions. Mathematically, they are analogous also, as may be seen from Figure 9. The well-known equation—

$$y = L(1 - 10^{-k_1 t}) \quad \ldots\ldots (1)$$

—of the B.O.D. test has its exact coun-

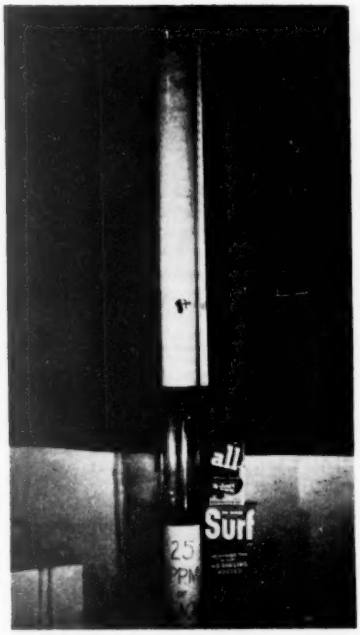


FIGURE 7.—Frothing of 25 p.p.m. of Surf as modified by 25 p.p.m. of non-sudsing All.

terpart in

$$b = S(1 - 10^{-k_2 t}) \quad \ldots\ldots (2)$$

of these aeration studies. The designation k_2 has been used purposely because it is the same as the reaeration constant, k_2, of the oxygen-sag curve of stream pollution. It thus serves as a reminder that the reaeration portion of the oxygen-sag curve is also a first-order reaction, and that these "aeration" studies are in reality "reaeration" studies, quite analogous to those of Streeter *et al.*, nearly 20 years ago (8)(9)(10).

Since Eq. 2 can be rearranged, thus:

$$\log \frac{S - b}{S} = -k_2 t \quad \ldots\ldots (3)$$

or, simply,

$$\log \frac{D}{S} = -k_2 t \quad \ldots\ldots (3a)$$

a plot of per cent deficiency ($D/S \times 100$) *versus* time yields a straight line on semi-logarithmic paper and a simple way to compute k_2, since the slope of

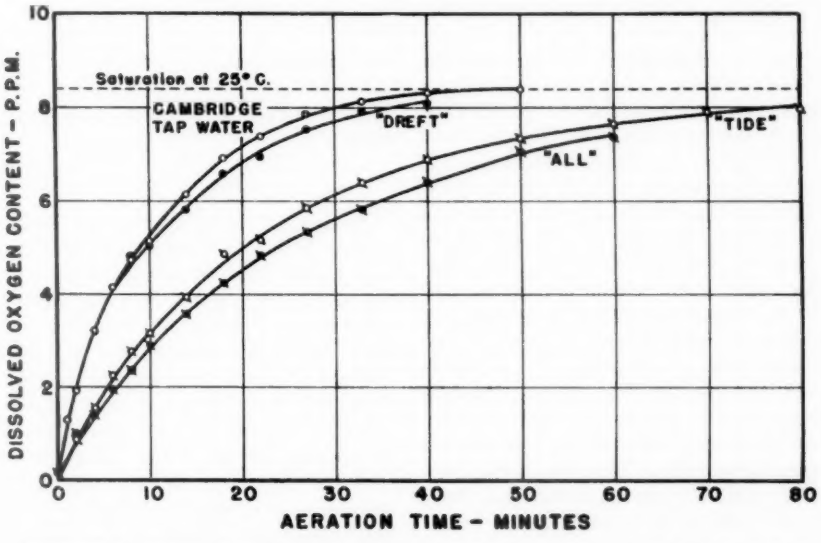


FIGURE 8.—Effect of 50 p.p.m. of certain retail detergents on oxygen transfer using diffused air.

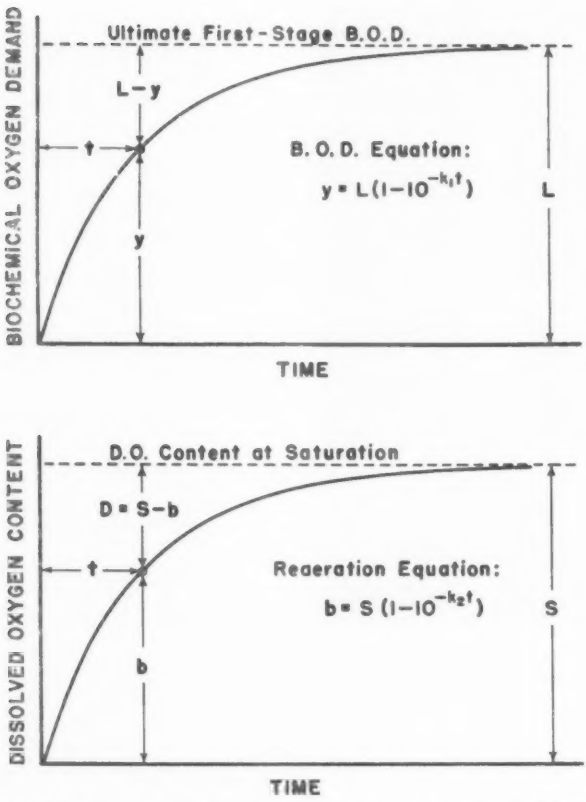


FIGURE 9.—Analogy between reaeration and first-stage B.O.D.

the line is numerically equal to k_2. Such computations of k_2 have been made for all the retail syndets studied. These values are shown in Table I, together with certain other data, and show that certain of the detergents interfere seriously with oxygen transfer. The item "relative time factor" is the time required to raise the dissolved oxygen content a given increment from a given level, relative to the time required in tap water alone. Numerically, it is equal to the k_2 for water divided by the k_2 for the respective syndets. This simple relationship follows from the differential form of the reaeration equation,

$$\frac{db}{dt} = 2.3k_2D \quad \ldots\ldots\ldots (4)$$

since db/dt is the rate of oxygen absorption.

Discussion

Although the frothing studies reported in this paper were conducted in tap water, and hence are not directly applicable to sewage, they do serve to suggest that whatever influence syndets have on frothing in activated sludge plants is not limited to questions of their absence or presence, their concentration, the concentration of aeration solids in the aeration tank, and the degree of purification of the sewage, but is further complicated by the considerable range in the frothing tendency of the various syndets themselves.

TABLE I.—Influence of 50 P.P.M. of Certain Retail Syndets upon Oxygen Transfer in Cambridge, Mass., Tap Water at 25° C.

Trade Name of Syndet	General Type	Presumed Active Agent[1]	Frothing Tendency	Oxygen-Transfer Constant, k_2 (per minute)	Relative Time Factor
Water[2]	——	——	——	0.0355	1.00
Vel	Anionic	A.B.S.	Strong	0.0392	0.91
Dreft	Anionic	A.S.	Strong	0.0332	1.07
Breeze	Anionic	A.B.S.	Strong	0.0252	1.41
Surf	Anionic	A.B.S.	Strong	0.0250	1.42
Cheer	Anionic	A.B.S. and A.S.	Strong	0.0225	1.58
Glim	Non-ionic	A.P.P.O.	Strong	0.0203	1.75
Joy	Non-ionic	A.P.P.O.	Strong	0.0198	1.79
Tide	Anionic	A.B.S. and A.S.	Slight	0.0187	1.90
All	Non-ionic	P.O.E.	None	0.0149	2.38
Fab	Anionic	A.B.S.	Moderate	0.0120	2.96
Oxydol	Anionic	A.B.S.	Slight	0.0119	2.98

[1] Organic fraction, from best available information:
A.B.S. = alkyl benzene sulfonate.
A.S. = alkyl sulfate.
A.P.P.O. = alkyl phenoxy polyethylene oxide.
P.O.E. = polyethylene oxide ester.

[2] Control.

These studies also revealed how misleading the frothing tendencies of syndets in washing machine or dishpan are as indices of their frothing action under other temperatures and conditions. To one who has observed the rich suds of Tide in the hot water of the dishpan, or the "controlled sudsing" of All in the hotter water of the automatic washer, their poor- and non-frothing characteristics, respectively, under the conditions of these studies seem quite noteworthy. It may explain why the plant-scale tests of frothing in the diffused air activated sludge plant at San Antonio, Tex. (11), led Gowdy to state (12): "To limit the conclusions to the facts these studies have shown, it does not appear that commonly sold household detergents play any important part in practical frothing problems encountered in the treatment of sewage by the activated sludge process." The "commonly sold household detergent" used there was Tide.

These frothing studies may, perhaps, be interpreted a little less cautiously as regards frothing in relatively clean river waters receiving treated effluents, although the syndet concentration used was higher than would be expected in such waters. Nevertheless, the variation in frothing found in such receiving waters takes on added interest when these studies are considered in the light of the findings of Bogan and Sawyer (13) in regard to the great variation in the susceptibility of syndets to biochemical oxidation. Many syndets are oxidized so slowly as to pass through biological sewage treatment plants largely undiminished in concentration, hence they are capable of frothing again when they reach the river.

Likewise, the oxygen transfer studies point to another potential problem in stream sanitation. Syndets which are unaffected by passage through biological treatment units might materially reduce the receiving capacity of the streams into which they are discharged. If a stream's reaeration constant, k_2, were reduced by the presence of syndets, its ability to assimilate oxidizable organic wastes without difficulty would be reduced to

a certain extent, because of the restricted availability of atmospheric oxygen.

Interpretation of these oxygen transfer studies to apply to activated sludge plants is almost completely in the realm of speculation. Nevertheless, if one imagines an activated sludge plant limited in blower capacity to the equivalent of the experimental system, it would be able to supply up to 38 p.p.m. of oxygen per hour to an activated sludge growing at 25° C., and still maintain aerobic conditions (0.5 p.p.m. of D.O.) in the aeration tank, provided the k_2 value were equal to that in tap water. Since oxygen is consumed in a conventional activated sludge plant at about 30 p.p.m. per hour, such a plant would operate satisfactorily. If, however, 50 p.p.m. of Oxydol, for example, had the same relative effect on oxygen transfer in sewage as it did in these studies in tap water, the rate at which oxygen could be supplied would drop to about 13 p.p.m. per hour, or far too low to maintain aerobic conditions. That such a severe reduction in plant efficiency would occur is unlikely, but it suggests one possible explanation as to why some plants have experienced difficulty in meeting the air requirements of their aeration systems. Further research is being conducted into the fundamentals of detergent interference with oxygen transfer.

Summary and Conclusions

Preliminary studies have been made of the frothing of 11 retail synthetic detergents and of their influence on oxygen transfer during aeration. These studies utilized diffused air aeration and were conducted in Cambridge, Mass., tap water at a temperature of 25° C. and at syndet concentrations of 50 p.p.m. (as marketed), in most cases.

On the basis of the research reported herein, the following conclusions are drawn:

1. Synthetic detergents vary markedly in their ability to suds, from severe frothing to no frothing at all, hence neither blanket condemnation nor blanket exoneration of their role in frothing difficulties at sewage treatment plants seems justified.

2. Those syndets which suds and which are resistant to biological degradation are capable of causing frothing difficulties in receiving waters, especially if relatively clean streams.

3. Most detergents reduce the rate of transfer of oxygen during aeration, but they vary widely in the degree of such reduction.

4. Syndets which gain entrance to receiving bodies of water are capable, in varying degrees, of reducing the reaeration constant, k_2. Because of the biological stability of many synthetic detergents and the fact that they are not precipitated by calcium and magnesium ions, this effect may persist for long distances downstream.

5. The serious interference with oxygen absorption caused by the heavy-duty syndets is corroborating evidence which supports the thesis that detergents are responsible for increased air requirements in activated sludge treatment of sewage.

Acknowledgment

This investigation was supported by a research grant from the National Institutes of Health, U. S. Public Health Service.

References

1. Symposium: "Effect of Detergents on Sewage and Water Treatment." *Chem. Eng. News*, **31**, 1072 (1953).
2. Sperry, W. A., "Detergents and Their Influence on Sewage Treatment." THIS JOURNAL, **23**, 12, 1469 (Dec., 1951).
3. Lumb, C., "The Effects of Synthetic Detergents on Sewage Purification: A Summary of Current Knowledge in

England." *Water and San. Eng.*, **3**, 1, 7; and **3**, 2, 53 (1952).
4. Todd, A. R., "Water Purification Upset Seriously by Detergents." *Water and Sew. Works*, **101**, 80 (1954).
5. Cross, J. T., Gallaher, W. V., Filicky, J. G., and Hassler, J. W., "Effects of Synthetic-Detergent Pollution." *Jour. Amer. Water Works Assn.*, **42**, 17 (1950).
6. Gowdy, W. R., "Chemical Structure and Action of Synthetic Detergents." THIS JOURNAL, **25**, 1, 1 (Jan., 1953).
7. Gowdy, W. R., "The Action of Detergents in Sewage Treatment—A Study by Industry." THIS JOURNAL, **25**, 3, 255 (Mar., 1953).
8. Streeter, H. W., "Measures of Natural Oxidation in Polluted Streams. II. The Reaeration Factor and Oxygen Balance." *Sewage Works Jour.*, **7**, 3, 534 (May, 1935).
9. Streeter, H. W., Wright, C. T., and Kehr, R. W., "Measures of Natural Oxidation in Polluted Streams. III. An Experimental Study of Atmospheric Reaeration Under Stream-Flow Conditions." *Sewage Works Jour.*, **8**, 2, 282 (Mar., 1936).
10. Kehr, R. W., "Measures of Natural Oxidation in Polluted Streams. IV. Effect of Sewage on Atmospheric Reaeration Under Stream-Flow Conditions." *Sewage Works Jour.*, **10**, 2, 228 (Mar., 1938).
11. Wells, W. N., and Scherer, C. H., "Froth Formation and Synthetic Detergents." THIS JOURNAL, **24**, 5, 670 (May, 1952).
12. Gowdy, W. R., "The Action of Detergents in Sewage Treatment—A Study by Industry." THIS JOURNAL, **25**, 3, 260 (Mar., 1953).
13. Bogan, R. H., and Sawyer, C. N., "Biochemical Degradation of Synthetic Detergents. I. Preliminary Studies." THIS JOURNAL, **26**, 9, 1069 (Sept., 1954).

INFORMATION URGENTLY NEEDED ON RELOCATION OF SEWERS UNDER FEDERAL AID HIGHWAYS

Problems posed by location and reconstruction of public utilities as a result of expanding Federal aid highway construction are complex and controversial. Reimbursement to the utilities is particularly complicated by the fact that a large percentage of the $2,000,000,000 appropriated for 1955 and 1956 will be expended on interstate highway systems.

To provide information for recommendations to Congress regarding financial reimbursement for necessary utility relocations under Federal aid highways, the Bureau of Public Roads is assembling pertinent data on this matter. Field work for the report is being done through the several State Highway Departments, each of which is acting through a State Utilities Committee set up for that purpose. The information is to be elicited from local utilities, both public and private, by a questionnaire dealing with utility work involved in Federal aid highway projects during 1953.

All Federation members and other *Journal* readers receiving such questionnaires are urged to fill them out completely and return them promptly to the requesting party. If sewer (sanitary, combined, storm or other) relocations were performed by reason of Federal aid highway work in 1953 and a questionnaire has not been received by October 15, 1954, the possibility should be investigated that the questionnaire has been directed to a mayor or public works official and has not reached the proper person to give all the detailed information on the projects. In case no questionnaire is received, a full description of any such project, including quantities and detailed costs, should be sent directly to the State Utilities Committee in care of the respective State Highway Commission.

Act promptly! The deadline date for submission of information is November 1, 1954.

PLANT-SCALE STUDIES OF THERMOPHILIC DIGESTION AT LOS ANGELES *

By William F. Garber

Laboratory Director, Hyperion Sewage Treatment Plant, Los Angeles, Calif.

As part of the engineering studies involved in the design of a sludge digestion system, it is apparent that several basic decisions must be reached as to the function of digestion at the particular site in question. Obviously, a cost study of solids reduction by sludge digestion with by-product gas and low-nitrogen solids production *versus* raw sludge processing is very important.

Then, if digestion is indicated, the capacity of the system and consequent digestion time must be determined. Since in normally operating units 80 to 90 per cent of the readily recoverable gas is produced within the first 10 to 20 days of digestion † (1), a decision must be made as to whether the sludge should be held only long enough to recover most of the gas or whether it should be digested completely. This in turn determines the size of the covered digesters needed, the necessity for secondary tanks and gas storage facilities, and the sludge processing procedures to be used. For example, a small plant which must dewater its sludge on drying beds might find that complete digestion with good supernatant separation is necessary, whereas a large plant with mechanical dewatering equipment or other adequate drying facilities might find primary digestion for gas production followed by sludge processing most satisfactory.

Covered, heated digesters need only be designed to recover the easily produced gas and to render the sludge inoffensive. The remaining necessary digestion and supernatant decantation can be accomplished in open tanks or lagoons with little or no danger or nuisance since, as previously indicated, the major part of the digestion process occurs in the first 10 to 20 days if adequate temperatures, seed, and mixing are present. It is doubtful that the 10 to 20 per cent of gas obtained from covered secondary tanks can justify the large capital costs of their construction. Tanks whose main function is sludge concentration and supernatant removal might better be designed for these functions alone.

Operation Factors

One of the important parameters involved in sewage sludge digestion is that of operating temperatures. The familiar mesophilic-thermophilic curve reported in many publications (2)(3)(4) illustrates the generally accepted concept of the effect of temperature upon sludge digestion. There is some difference of opinion, but the optimum temperature for mesophilic digestion is assumed to be somewhere in the range between 85° and 100° F., whereas that for thermophilic digestion is between 120° and 140° F. The range between 100° and 120° F. is considered to be one in which neither the mesophilic nor thermophilic organisms can prosper; so digestion at these temperatures is not advised. At the Hyperion plant, operating temperatures of 85°, 100°, and 120° F. have been used.

Digestion at temperatures above 100° F. has been studied many times

* Presented at 1954 Annual Meeting, California Sewage and Industrial Wastes Assn.; Sacramento, Calif.; May 5–8, 1954.

† Hyperion experience shows 90 per cent gas production in 15 days.

on a laboratory scale (4)(5)(6)(7)(8)(9). In addition, at least one plant-scale test (10) has been reported. The decision to make plant-scale trials of 120° F. digestion at Hyperion was not based upon a desire to try to increase either the capacity of the existing plant or the gas production as was true of many of the earlier investigations. Rather it came about as part of a program that had been initiated soon after plant operation had begun with the object of examining the relationship between conditions of digestion and sludge elutriation, conditioning, and dewatering. The Hyperion digestion system is adequate for the digestion of raw solids captured from flows considerably in excess of those now received. Therefore, throughout the period of 120° F. operation, a portion of the system has used either 85° or 100° F. temperatures. Data are therefore available on parallel runs at all three temperatures.

Hyperion raw sludge that has been digested at 85° or 100° F. is apparently well-digested by all the indices commonly used for such evaluations. It is, however, difficult to elutriate, chemically condition, and dewater on vacuum filters. A possible added parameter in the engineering evaluation of digestion system design is suggested by this fact. That is, within the range of well-digested sludge as determined by the usual analyses, are there operational conditions that can drastically effect sludge solids disposal?

Since such solids processing was causing a heavy drain on the Hyperion operational budget, studies were instituted to try to evaluate this point and subsequently bring these expenses within the range common to most plants using similar solids disposal methods. In the course of these studies many coagulants were tried, different types of filter blankets were used, many variations in the operation of the vacuum filters and the elutriation system were made, different methods of cloth and filter cleaning were tried, and a thorough study of the digestion process itself was carried on. In the study of the digestion process an attempt was made to determine the following:

1. Was one-, two- or three-stage digestion the most beneficial from the standpoint of operation, loading, completeness, and ease of dewatering?
2. Could digester charging and loading practices be changed with benefit to both digestion and dewaterability?
3. Were there industrial wastes or materials such as ether solubles and synthetic detergents which were adversely affecting dewaterability?
4. Were there characteristics of the sludge solids or of the sludge organisms which inhibited dewatering?
5. Did the temperature of digestion have any effect on the processing of the digested sludge?
6. What was the effect of different types of mixing on digestion and dewatering?
7. Could the elutriated digested sludge be concentrated to a degree such that the dewatering problem would be improved?

This paper considers the foregoing points in two sections, the first covering the general problems of digestion examined during the investigation and the other reviewing in detail digestion at 120° F.

General Investigation

The Hyperion sewage treatment plant is a high-rate or modified aeration secondary treatment plant with an average flow of about 230 m.g.d. The waste sludge from the secondary sedimentation system is returned to the head of the primary settling system, where it is settled with the primary solids. Of the average of about 1.237 m.g. of raw sludge with 6.63 per cent solids pumped to the digestion system each day, about 30 per cent is raw secondary solids and 70 per cent is raw primary solids. This mixed raw

sludge is removed from the primary settling system on a continuous basis, with each primary digestion tank being charged a set amount in rotation. On this basis each primary digester is charged from one to two times daily. Floating solids and skimmings are removed from the primary sedimentation tanks at intervals and are added to the primary digestion tank being charged at that particular time. All primary digesters receive about the same amount of such scum and grease.

The digestion system is composed of 12 primary digesters and 6 secondary digesters, arranged so that two primaries feed one secondary (Figure 1). During most of the past two years of operation an average of 10 primary tanks and 5 secondary tanks have been used. Each digestion tank is about 111 ft. in diameter and 30.5 ft. deep at the side wall, with a total liquid volume of 2,538,500 gal. Each arrangement of two primary tanks and one secondary thus has a total volume of 7,615,500 gal. Gas production for the entire system is about 4,800,000 cu. ft. per day of a product with a low heat value of 590 B.t.u. per cu. ft. Sludge heating in the primary tanks is accomplished by direct steam injection through draft tube mixers. Secondary tanks are not equipped for supplementary heating. Mixing is by draft tube mixers and/or by recirculation pumps (Figure 2). The digested sludge removed from the secondary tanks is elutriated, dewatered on vacuum filters, heat dried, sacked, and delivered to a contractor for sale as fertilizer. With the exception of some bulk sales, all the digested solids recovered are disposed of in this manner. Further data covering detention time, volatiles reduction, and gas production rates are listed in Table I.

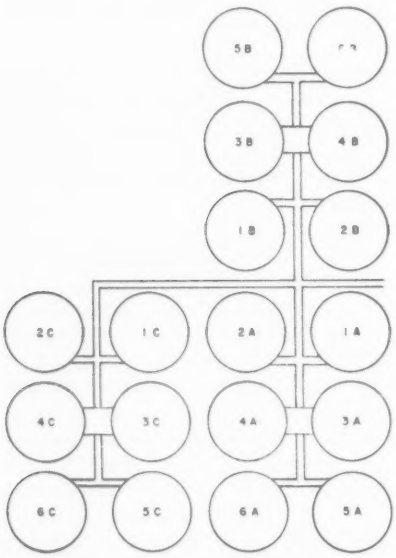


FIGURE 1.—Arrangement of 12 primary and 6 secondary digesters at Hyperion plant.

Various Operational Methods Tried

A number of operational variations were tried in the digestion system before temperature increases were used. Considerable information on operational procedure and acceptable loads was developed during these studies, but no benefit accrued to the major problem of sludge filtration. However, it became apparent that manipulations within the 85° to 100° F. temperature range had little effect on either the progress or the final result of the digestion process. This fact then argued for a relatively radical change in one of the important variables of anaerobic culture control; since temperature could be most easily altered, this step was decided upon. Table I outlines the most important of the studies leading to the decision, and allows close comparison to be made between them.

Multiple-Stage Digestion

Columns 3 and 8 (Table I) show that for a given loading rate and digestion temperature within the mesophilic range, it makes little difference whether one-, two- or three-stage digestion is practiced if adequate mixing

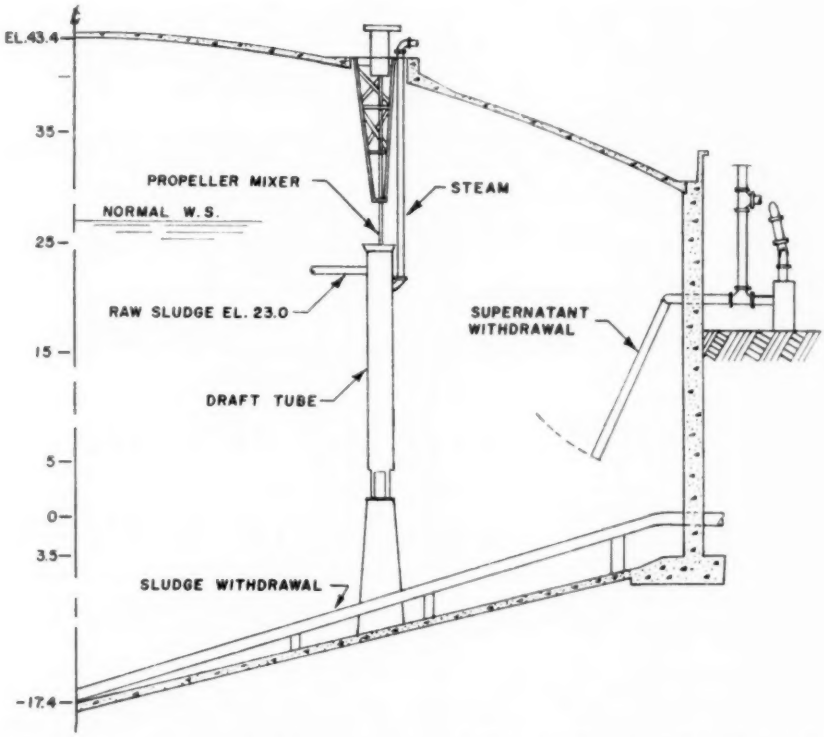


FIGURE 2.—Heating and mixing arrangement of Hyperion digesters. Secondary tanks are not equipped for supplementary heating.

and seeding are present. There are some differences in the per cent reduction of volatiles under each system; but these are probably due to the differences in mixing, raw sludge charged, and analytical techniques, rather than to digester performance. Thus, column 3 shows that a primary tank under normal operation and a single load reduces the volatile solids by 56.4 per cent, whereas the primary and secondary stages of the three-stage digester (column 8) reduce the volatiles by 57.1 per cent under a slightly lower total load. Similarly, the two stages of column 3 are as effective as the three stages of column 8, under the same load. Apparently, from the standpoint of solids reduction alone, a single-stage digester is as effective as a multi-stage digester when equivalent conditions exist.

Sludge Concentration

It was postulated that if the solids content of the elutriated sludge reaching the vacuum filters could be substantially increased, the amount of filtrate to be removed would be considerably less and filter production would correspondingly increase. Laboratory studies showed this to be correct, so two avenues of achieving such concentration were tried.

The first of these involved manipulations in digester operations, and the second, sedimentation of elutriated sludge. Under the normal operating procedures, as raw sludge is charged to the primary tanks, primary sludge is

TABLE I.—Comparison of Operational Tests on Different Methods of Digestion

Item	Tanks	Normal Operation,[1] 85° F.		Normal Operation,[1] 100° F.		Normal Operation,[1] 120° F.		70-Day Detention,[2] 100° F.	3-Stage Digestion,[3] 100° F.	Fill-Rest-Draw,[4] 100° F.	Skimmings Digestion,[5] 100° F.
		Single Load[6]	Double Load[7]	Single Load[6]	Double Load[7]	Single Load[6]	Double Load[7]				
		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Time process used (months)	—	12	6	6	6	12	9	7	10	4	4
Raw sludge solids (%)	—	6.50	6.22	6.19	6.20	6.29	6.34	6.49	6.50	6.75	2.15
Raw sludge vol. sol. (%)	—	75.2	76.5	76.5	76.7	75.4	76.6	74.1	75.2	75.2	58.0
Dig. sludge solids (%)[8]	Prim.	3.67	3.09	3.90	3.89	4.59	5.12	3.08	3.84	3.58	3.15
	Sec.	3.40	—	2.98	3.70	3.95	—	2.88	3.54	3.19	—
	Tert.	—	—	—	—	—	—	—	3.21	—	—
	Total	3.40	—	2.98	3.70	3.95	—	2.88	3.21	3.19	—
Dig. sludge vol. sol. (%)	Prim.	58.8	62.5	58.6	61.8	58.8	60.0	56.7	59.4	58.6	40.5
	Sec.	56.5	—	56.9	59.5	57.6	—	53.2	56.7	56.2	—
	Tert.	—	—	—	—	—	—	—	55.5	—	—
	Total	56.5	—	56.9	59.5	57.6	—	53.2	55.5	56.2	—
Volatile acids (p.p.m.)[9]	Prim.	93	212	117	93	648	845	128	116	148	88
	Sec.	72	—	77	72	275	—	88	88	140	—
	Tert.	—	—	—	—	—	—	—	83	—	—
	Total	72	—	77	72	275	—	88	83	140	—
Alkalinity (p.p.m.)	Prim.	4582	3839	3842	4286	4070	3902	4153	4165	—	3738
	Sec.	4902	—	4125	4775	4225	—	4514	4449	—	—
	Tert.	—	—	—	—	—	—	—	4715	—	—
	Total	4902	—	4125	4775	4225	—	4514	4715	—	—
pH	Prim.	7.3	7.1	7.4	7.3	7.5	7.4	7.3	7.3	7.3	7.3
	Sec.	7.4	—	7.6	7.4	7.5	—	7.4	7.4	7.4	—
	Tert.	—	—	—	—	—	—	—	7.4	—	—
	Total	7.4	—	7.6	7.4	7.5	—	7.4	7.4	7.4	—
Dig. loading (lb./cu. ft./mo.)[10]											
Total solids	Prim.	4.53	9.49	4.66	9.60	5.10	9.36	3.93	9.09	4.36	2.60
Volatile solids	Prim.	3.41	7.26	3.56	7.46	3.85	7.18	2.90	6.83	3.38	1.51
Total solids	Sec.	—	—	—	—	—	—	—	4.55	—	—
Volatile solids	Sec.	—	—	—	—	—	—	—	3.42	—	—
Total solids	Total	3.02	—	3.55	6.05	3.40	—	1.97	3.03	2.91	—
Volatile solids	Total	2.27	—	2.71	4.64	2.56	—	1.47	2.28	2.19	—

Detention time (days)	Prim.	29.0	12.5	25.7	14.2	23.5	12.5	35.9	14.4	30.0	24.2
	Sec.	14.5	—	12.8	8.4	11.8	—	35.9	14.4	15.0	—
	Tert.	—	—	—	—	—	—	—	14.4	—	—
	Total	43.5	—	38.5	22.6	35.3	—	71.8	43.2	45.0	—
Vol. sol. reduction (%)	Prim.	53.3	48.6	56.4	50.7	53.5	54.4	54.7	51.9	53.3	50.7
	Sec.	3.6	—	3.2	4.5	2.1	—	5.7	5.2	4.4	—
	Tert.	—	—	—	—	—	—	—	1.7	—	—
	Total	56.9	—	59.6	55.2	55.6	—	60.4	58.8	57.7	—
Tot. sol. reduction (%)	Total	42.8	37.2[12]	45.6	42.4	41.9	41.7[12]	44.2	44.2	43.4	29.4[12]
Gas produced (cu. ft./lb. vol. destroyed)	Prim.	18.0	17.5	19.0	19.0	17.8	15.2[13]	22.4	16.8	18.2	22.3
	Sec.	—	—	—	—	—	—	20.8	—	—	—
	Sec. & tert.	—	—	—	—	—	—	—	19.4	—	—
	Total	18.2	—	18.3	17.9	18.0	—	22.1	17.1	17.7	—
Ether sol. (% of dig. sl.)[11]	—	13.2	13.2	13.2	13.2	13.2	13.2	13.2	13.2	13.2	13.2[14]
Scum formation	—	Normal	Normal[15]	Normal	Normal[15]	Normal	Normal[15]	Normal	Normal[16]	Normal	Normal

[1] Raw sludge fed to primary, primary digested sludge simultaneously transferred to secondary, supernatant decanted from secondary, and secondary digested sludge removed at the same time.

[2] Average of operation, using normal and fill-rest-draw methods.

[3] Continuous flow with recycling of 25 to 40 per cent third-stage sludge to primary digesters as seed; no supernatant removal.

[4] Primaries loaded for 24 hr.; primaries and secondary rested for 24 hr. (secondary under quiescent conditions); supernatant and digested sludge withdrawn for 24 hr.

[5] Complete charge to two primary tanks made up of skimmings from primary sedimentation tanks; normal operating procedures.

[6] Design load was 4.86 lb. of total solids per cu. ft. per month in primaries, and 3.24 lb. per cu. ft. per month in primary plus secondary; single loading approximately this.

[7] Twice the single loading.

[8] Based on a 50-50 discharge of bottom and supernatant sludge; the values for these were then averaged.

[9] Probably high; this is an empirical test for control, and the method of procedure produces somewhat high results.

[10] Calculated by using volume of primaries alone for primary figure, and primaries plus secondary for total battery figure. Three-stage digestion used primary volume, primary and secondary volume, then primary and secondary and tertiary.

[11] No significant difference noticed in utilization of ether solubles by the methods studied; general average 13.2 per cent, with 10 per cent of this saponifiable, 82 per cent non-saponifiable, and 8 per cent mineral salts and glycerol. Raw sludge 24.4 per cent ether solubles with 25.8 per cent non-saponifiable, 74.2 per cent saponifiable. Fertilizer, 9.9 per cent ether solubles.

[12] Primary tanks only.

[13] Probably too low, since it includes period during which 120° F. digestion was becoming fully established; the last two months averaged 16.0.

[14] Charge was 74 per cent ether solubles, with 81 per cent of this being saponifiable and the remaining 19 per cent non-saponifiable. The digested material discharged had about the same ether-soluble content as normal digested sludge.

[15] Seemingly less scum troubles; felt to result from greater mixing by greater total of gas production.

[16] The scum on the second of the three stages became very thick; probably due to very little gas mixing and no mechanical mixing devices.

automatically transferred to the secondary tank while digested sludge and supernatant are concurrently removed from it. The characteristics of 85° to 100° F. Hyperion digested sludge were such that under these methods poor supernatant separation occurred and low-solids digested sludge was obtained.

Consequently (column 9, Table I), a "fill-rest-draw" method of operation was instituted. In this, a digester battery was charged 24 hr., then rested for 24 hr., with mixing in the primaries and quiescent conditions in the secondaries, then supernatant and digested sludge were removed for 24 hr.

It was thought that better supernatant separation might be achieved in this manner and also that somewhat better digestion might occur, since there was no possibility of a raw sludge by-pass. It was found that this process gave no increased supernatant separation and, therefore, no increase in the solids content of the sludge removed. In addition, no increase in solids digestion was observed. In fact, as suggested by Imhoff (11) and Rankin (12), the disadvantages of a batch process over continuous flow seemed to apply because, as columns 3 and 9 (Table I) show, the degree of digestion and gas production was substantially less.

Further study showed that for the mesophilic range the only method which gave good supernatant separation was long detention (column 7, Table I). Apparently, during the long relatively complete digestion of the solids, the rate of gas production was reduced to a point such that gas stirring did not interfere with supernatant separation. However, the destruction of sludge solids during long detention was only slightly more than observed under normal loadings and the total gas produced was actually less. The net result was, therefore, decreased digestion capacity and gas yield, which the improvement in supernatant separation could not justify.

In a further attempt to concentrate the sludge prior to filtration, digested elutriated sludge with about 4% solids was pumped into an empty digestion tank and allowed to settle. At the end of about 25 days the solids concentration had risen to 7 per cent, but the alkalinity had increased from about 700 p.p.m. to almost 1,400 p.p.m. Obviously, further digestion which hampered sedimentation and produced a virtually unfilterable sludge had occurred. These results had not been anticipated, as tests using 50-gal., 100-gal., and 2,500-gal. quantities of the elutriated sludge had indicated that a 7 per cent solids content could be achieved in less than 5 days. The reason for the extended sedimentation period found necessary in the 2.5-m.g. tank is suggested by the area loading concept of Torpey and Lang (13). Thus, in Table II it can be seen that the quotient obtained by dividing the initial load on each of the tanks by the time necessary to reach the optimum solids level can be thought of as the load in pounds per square foot per day, and is approximately equal for all of the tanks tested. Therefore, the time necessary for a given sludge to achieve a certain concentration is seemingly a function of tank area and the initial solids load.

It is apparent that use of covered digestion tanks for such service is both unsatisfactory and uneconomical. Tanks to be used for solids concentration should be designed for such purposes to be efficient and saving of capital expense. Use of the area loading concept on the installed sludge

TABLE II.—Sedimentation Rate of Digested Elutriated Sludge

Tank Vol. (gal.)	Surface Area (sq. ft.)	Initial Load (lb./sq. ft.)	Days to 7% Conc.	Loading Rate (lb./sq. ft./day)
50	3	5.6	1.7	3.3
100	3	11.1	3.4	3.3
2,100	28	24	6	4.0
2,538,000	9,500	87	25	3.5

elutriation and concentration tanks at Hyperion has resulted in a continuous-flow process yielding a sludge with 7 to 8 per cent solids. This has greatly simplified operational control and has enabled the use of the digestion tanks for their designed function.

Effect of Ether Solubles

Because it had been found that the ether solubles content of the Hyperion raw sewage averaged 140 p.p.m., while that of the raw sludge averaged 24.4 per cent, it was felt that the poor filterability might arise in part from this material. To examine the effect of ether solubles on digestion, two primary digestion tanks were charged with primary sedimentation tank skimmings to 100 per cent of their load for a 4-month period. The experimental results obtained are tabulated in column 10, Table I. From this it is clear that a material with high ether solubles will digest quite satisfactorily and that the filterability of the product within the mesophilic range was equally as good or as poor as digesters operated with normal raw sludge. As in all the other digesters, the saponifiable fraction of the ether extraction can be digested, whereas the non-saponifiable material, thought to be chiefly mineral oils, cannot. The sludge from the other digestion tanks during the period of separate skimmings digestion did not show improved filtration characteristics.

Effect of Industrial Wastes

It had also been intended that the incoming raw sewage be examined for industrial waste materials that might affect both digestion and filtration. Work on 120° F. digestion had indicated that this is not the source of the filtration problem, so no work along this line was done.

Mixing

The experimental work, to date, has made it clear that adequate mixing of the raw feed sludge with the seed mass is very necessary. Several methods of doing this are known and some have been tested at Hyperion. Some mixing processes can increase the percentage of fine solids slightly and thus affect filtration yields. Experience indicates, however, that such solids comminution is a minor factor.

Multiple Loading

Table I, columns 1 through 4, compares normal operations within the mesophilic range at 85° and 100° F. In addition, the effect of single and double loads is shown. It is readily apparent that operation at the higher temperature results in a slightly greater reduction in the volatile and total solids content of the digested sludge. In the single-charge batteries, the reduction of volatiles in primary tanks at 100° F. was increased 5.5 per cent over those at 85° F. For primary plus secondary tanks the percentage increase was 4.5 per cent. The double-charged tanks paralleled this, with the 100° F. primary tank giving a percentage increase of 4.2 per cent over similar 85° F. stages. As a result of these data, it was decided to operate all low-temperature tanks at Hyperion in the 83° to 86° F. temperature range. The filtration, drying, and digestion capacities are such that 4 to 5 per cent decrease in solids destruction is of little concern; and gas production is more than adequate for present needs. In addition, operation at the lower temperature allows a considerable saving in heat, and, since radiation losses are reduced during the colder months, heat levels are more easily maintained.

Ultimate Capacity

To obtain information on the ultimate capacity of the digestion system, some batteries were operated at a load of 9.55 lb. per cu. ft. per month of total solids in the primary tanks, and 6.05 lb. per cu. ft. per month in the full battery, or twice the design level.

Comparison of columns 2 and 4 (Table I) with columns 1 and 3, respectively, showed the solids reduction in the double-loaded primary tanks to be 49.7 per cent *versus* 54.8 per cent for the single-loaded tanks, or a difference of 9.5 per cent. The double-loaded primary plus secondary tanks gave a 55.2 per cent reduction in volatiles, whereas similar single-loaded batteries gave a 59.6 per cent reduction, or a 7.5 per cent difference. The total solids relationships were quite similar.

As can be seen, no operational difficulties developed under such a loading program.

The conclusions to be drawn from this are obvious. Doubling the loading decreases the percentage of solids reduction and total gas production by less than 10 per cent, while introducing no operational problems. Thus, installed digestion capacity is apparently at least twice the design figure and is adequate for the foreseeable future. An added benefit to the increased capacity is the fact that under the heavier loadings scum difficulties were at a minimum. It is felt that this resulted from the heavier gas production and, thus, increased gas stirring of the sludge mass. Some work

TABLE III.—Characteristics of Sludge Digested at 85° to 100° F. and at 120° F.

	85° to 100° F.		120° F.	
	Single Charge	Double Charge	Single Charge	Double Charge
Wet screen analysis (% passing 200-mesh)	80	80	65	65
Predominant bacterial forms	Coccus forms with gelatinous sheaths.		Rod- and chain-type organisms with no gelatinous sheaths.	
Methane in gas (%):				
Primaries	67.2	67.2	67.1	67.1
Secondary	67.6	67.6	72.5	72.5
Total	67.2	67.2	67.7	67.7
Volatile acids (p.p.m.):				
Primaries	105	152	648	845
Secondary	75	75	275	—
Volatile reduction (%)	58.2	54.0	55.6	54.4[1]
Digester loading (lb./cu. ft./mo.):				
Primaries, total solids	4.60	9.55	5.10	9.36
vol. solids	3.48	7.36	3.85	7.18
Full battery, total solids	3.28	—	3.40	—
vol. solids	2.49	—	2.56	—
Gas prod. (cu. ft./lb. vol. destroyed)	18.2	17.9	18.0	15.2[1,2]
Organic N, 100% dry vol. solids (%)[3]	2.75	—	1.90	—
Filtering char. elut. sludge:				
Yield (lb./sq. ft./hr.)[4]	1.7	1.7	6.3	6.3
Coag. demand, $FeCl_3$ (%)[5]	6.5	6.5	3.4	3.4
pH:				
Primaries	7.3	7.3	7.5	7.4
Secondary	7.4	7.4	7.5	—
Solids, digested sludge (%):				
Primaries	3.79	3.49	4.59	5.12
Secondary	3.19	3.70	3.95	—

[1] Primary tanks only.

[2] Value too low; high-temperature digestion not fully established during first part of experimental period.

[3] Elutriated.

[4] Solids content of sludges filtered approximately the same.

[5] Dry solids basis.

has been done with loadings in excess of those shown. Indications are that under adequate control triple loads may be possible.

Digestion at 120° F.

On January 1, 1952, as part of the long-range investigation of the role of digestion in sludge conditioning and filtration, it was decided to gradually increase the temperature of one battery of two primary tanks and one secondary to 120° F. By March 1952 this temperature had been reached, and from then until September 1952 an average of 20 per cent of the total raw sludge production was digested at the 120° level. During August 1952 another set of two primary tanks and one secondary tank was brought up to temperature. Between September and December 1952, therefore, 42 per cent of the raw sludge was digested at 120°.

In December 1952 a plant-scale elutriation and filtration test was made on the 120° sludge, during which this material was removed from all but one primary tank. Therefore, during January 1953 only 8 per cent of the raw sludge was digested at the 120° temperature. Between February and June 1953, an average of about 30 to 35 per cent of the raw sludge was digested at this temperature. From June 1953 to May 1954, about 50 per cent of digestion has been at 120°. The balance of the raw sludge has been digested in the 85° to 100° F. range.

There are basic differences between the sludges produced by the 85° to 100° and the 120° digestion processes. Experimental data covering the chief characteristics are tabulated in Table III.

Operationally, 120° digestion has posed no unusual problems other than the difficulty of maintaining heat during the winter months when radiation losses are high. At an early stage of operation it was thought that scum layers were thicker in the high-temperature tanks; but it is now felt that there is little difference in scum formation over that in the 85° to 100° range. By study of the microscopic flora present and of operating data, such as gas production, it was determined that almost 6 months were needed to establish the first 120° tank as a separate culture. Since that time, by seeding and by more rapid increases in temperature, the time has been cut to about 3 months. Experience has shown that once the 120° culture is established it is quite stable and resistant to upset. There have been variations in temperature of as much as 9° in 48 hr., but this has not affected the digestion in any detectable way. Table IV shows a typical range of temperatures recorded in three 120° digestion tanks over a month of moderate weather. An average of 120° F. usually is maintained over each month.

On occasions tanks in which 120° cultures had been established have been carried at a 110° level for periods of more than a month. It has been found that during such times the mesophilic organisms gradually begin to re-establish themselves, so that at the end of the period a mixed culture has been

TABLE IV.—Typical Temperature Readings for Thermophilic Digestion Tanks

Date	Temperature (° F.)		
	Tank 2B	Tank 2C	Tank 6C
4/1/53	119.6	121.1	120.3
4/3/53	122.5	115.7	117.1
4/5/53	121.5	112.8	114.4
4/7/53	118.3	114.9	113.4
4/9/53	119.6	108.3	113.2
4/11/53	120.2	109.5	115.6
4/13/53	117.0	112.2	113.2
4/15/53	110.6	119.5	111.0
4/17/53	115.9	120.1	115.7
4/19/53	118.4	119.5	112.2
4/21/53	120.6	123.6	112.3
4/23/53	119.0	116.9	120.2
4/25/53	124.8	112.1	118.6
4/27/53	122.1	123.7	119.4
4/29/53	120.0	121.6	120.9
Average	119.3	117.4	115.8

working quite satisfactorily. When temperatures were increased, the 120° organisms again predominated. The temperature in a 120° tank has never been dropped back to 85°, but this probably could be done quite abruptly if proper mesophilic seeding was used. Almost certainly no difficulties would develop if the temperature change was gradual.

The range between 100° and 120° F. has not been explored to see at just what critical point the culture changes. Experience leads to the belief that there may be no critical point, but rather a gradual shading from one type of organism to the other. In addition, in the range examined there seems to be no significant change in the rate of digestion once a culture proper to a certain operating temperature is established. Figures 3 and 4 illustrate this quite clearly. It is intended to examine these points more carefully at a later date.

Of particular interest to this plant were the characteristics of the 120° sludge leading to improved vacuum filter yields. The elutriated sludge produced from the 85° to 100° digesters has always been difficult to dewater. Other plants report yields in excess of 5 lb. per sq. ft. per hr. using 2 to 4 per cent of coagulant; but as Table III shows, Hyperion yields were much poorer.

Earlier work at this plant had established that there was a direct relationship between sludge particle size, filtration rate, and coagulant demand. Tests on sludge from other plants on the West Coast, exhibiting high filter yields and low coagulant demands, showed that their digested sludge contained from 68 to 73 per cent of material passing a 200-mesh screen, whereas the Hyperion digested sludge averaged 80 per cent passing. The percentage of fines in the Hyperion raw sludge was essentially the same as that of the 85° to 100° digested sludge. Screen analysis of the 120° sludge showed only 65 per cent passing so, from this alone, a substantial improvement in filtration conditions was predicted.

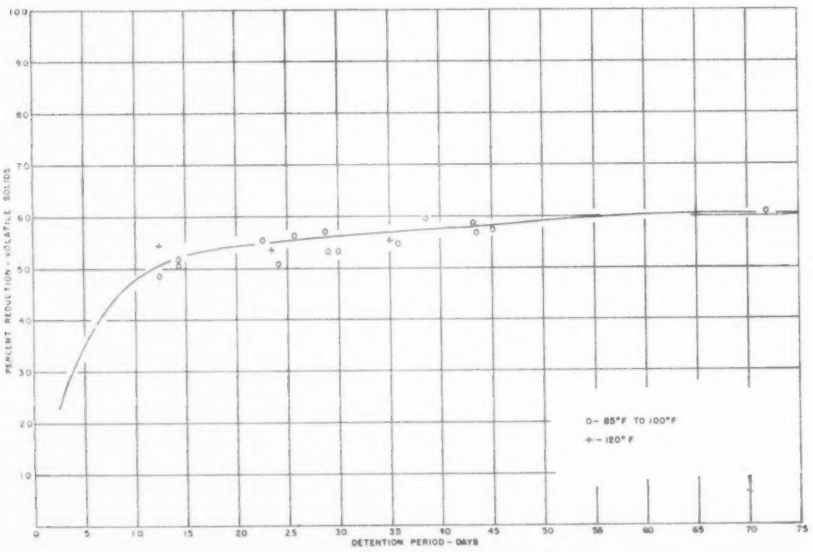


FIGURE 3.—Effect of digestion time on volatile solids reduction at 85° to 100° and 120° digestion temperatures.

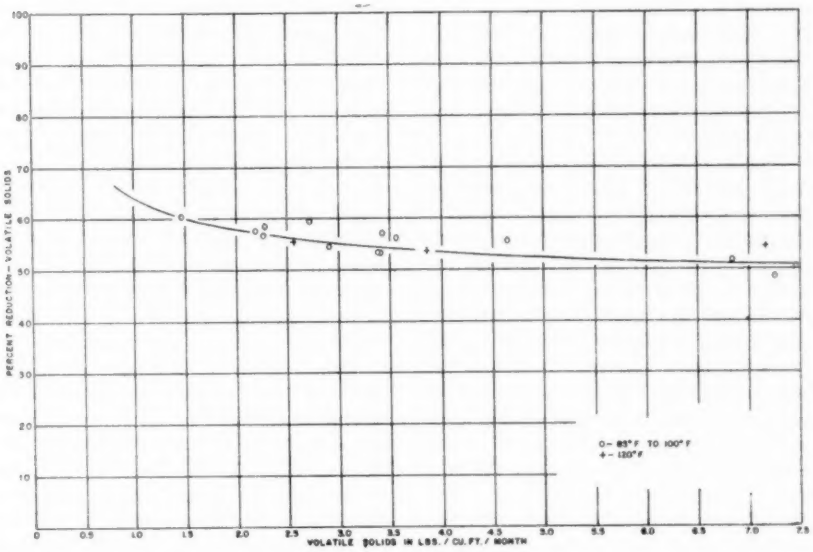


FIGURE 4.—Effect of loading rate on volatile solids reduction at 85° to 100° and 120° digestion temperatures.

However, plant-scale filtration tests gave results somewhat better than could be explained using the particle size concept alone. Microscopic examination of the type of organisms present in each temperature culture led to the postulation that the coccus forms with their gelatinous sheaths acted to plug the filter blankets when the 85° to 100° sludge was filtered, while no such blanking occurred when 120° sludge with its rod-type organisms was processed. The fact that when the lower temperature sludge was filtered, quantities of a gelatinous substance were always found on the under filter conveyor belts and on portions of the filters themselves tended to uphold this hypothesis. In addition to this, filter blanket life has been substantially increased since mixtures of the two sludges have been used. It is believed, therefore, that the decreases in the percentage of solids passing a 200-mesh screen, coupled with the presence of rod-shaped organisms having no gelatinous sheaths, account in large part for the increased filter yields and lowered coagulant demands.

Elutriation must still be used to reduce the bicarbonate alkalinity and the concentration of other digestion products prior to filtration. The major percentage increase in filtration rate accrued from the 120° process, but the sludge would still be virtually unfilterable without elutriation.

The basic reasons for the change in sludge characteristics must still be determined, as must the exact nature of the bacterial cultures involved. Sawyer (14) has suggested the possibility that a significant portion of the raw sludge charged to the primary digestion tanks is "living sludge" arising from the assimilative reactions produced by facultative organisms during the long transport period in the sewers and in the primary sedimentation tanks. He feels that such a "living sludge" fraction, being facultative, might pass unchanged through the digestion process at ordinary operating temperatures and affect sludge condi-

tioning and filtration. Operation in the 120° range might destroy this sludge fraction and allow considerable filtration improvement. Several lines of investigation are being pursued on this aspect.

The lower nitrogen content of the dried elutriated 120° solids and the somewhat higher methane content of the gas is quite characteristic of the process. The pH of the digested 120° sludge is about the same as that from 85° or 100° digesters; so it is probable that no extra nitrogen escapes as NH_3 gas. It seems likely that the protein content of the sludge is more completely digested at the higher temperatures, giving a subsequent greater formation of $(NH_4)HCO_3$, which is lost during the elutriation process. The higher methane content of the gas probably also arises from the greater digestion of the proteins. Why the amount of solids passing a 200-mesh screen is cut from 80 per cent to 65 per cent by this type of digestion is not known. Possibly there is a heat coagulation of the solids, or perhaps the more complete digestion of the protein fraction is an important factor. It may also be possible that the 120° organisms split the solids differently, actually cause a synthesis of larger particles, or act as suggested by Sawyer. In 85° to 100° operation the number of fines increases slightly during the digestion process. It is probable that this is chiefly due to the mechanical action of the mixers and recirculation pumps. The study of this phenomena promises to be difficult but rewarding.

It would seem logical in terms of the data presented to operate the entire Hyperion digestion system at 120° F. There are three main deterrents to this at the present time. The first of these is the fact that the nitrogen content of the 120° sludge will not meet current contract guarantees; the second is that the dried product is in stiff competition with organic nitrogen sources, such as steer manure, so substantial lowering of the nitrogen content makes disposal more difficult; the third is that the heat requirements could not be met during the winter months when the blower engines were down for routine maintenance, and steam production was thus at a minimum (vapor phase cooling). Present plant policy is to blend 120° and 85° sludges to a point such that the processed mixture maintains a satisfactory nitrogen level and filtration difficulties and coagulant demand are at a minimum.

Comparison of the operational results on high-temperature digestion obtained at Hyperion with those obtained at Jackson, Mich., by Fischer and Green (10) yields some interesting information. However, since the Jackson digesters were operated at 125° on a raw sludge feed containing 75 per cent secondary solids, whereas Hyperion has operated at 120° on a feed containing 30 per cent secondary sludge, some differences must be expected. At Jackson it was noted that a temperature variation of ± 5° F. in the 115° to 120° range was quite serious and could lead to the cessation of digestion for a period.

No such phenomenon has been noticed at Hyperion. However, good supernatant separation was found in the secondary digesters at both plants. At Jackson it was concluded that two-stage digestion was needed, whereas at Hyperion single-stage digestion is deemed adequate. In addition, the filtration characteristics of Hyperion single-stage 120° sludge have been excellent. At both plants direct steam injection was found to be an excellent method of heating.

At Hyperion no benefit to scum control was found, whereas the opposite was true at Jackson. The experiments at Jackson were directed toward finding a method for increasing digestion capacity and gas yields. At Hyperion no such increased capacity was noticed, but filtration characteristics were vastly improved. Both studies showed

the method to be operationally feasible and worth considering if economic considerations showed the high-temperature products to be desirable.

To summarize, the 120° process is operationally sound and solves in great part the chief filtration problems. However, there are a number of questions that have been opened by the method. These include the necessity of finding a fully logical explanation for the improved filtration yields; the exploration, both in the laboratory and in the plant, of digestion at temperatures between 100° and 130° F. to see if operating levels of even greater benefit are present; the observation of the behavior of a 120° culture dropped back to 85° F.; the determination of critical points that might exist, such that above or below them radically different cultures and operational behavior occurs; pure culture studies of the microorganisms to see what part they might play in particle size changes, nitrogen content, and physical characteristics of the sludge; and the blending of all of these into a set of logical parameters for the planning and control of digestion and filtration processes.

Summary and Conclusions

1. Under similar conditions of operating temperature, loading, mixing, and seeding, three-stage and two-stage digestion had no advantage over one-stage digestion.

2. Manipulations and variations in operational procedures within a given temperature range had little effect on the progress and final result of a digestion process if mixing and seeding were adequate.

3. Sludge concentration by sedimentation in tanks designed as digesters was not satisfactory or economical. It was concluded that such concentration should be in tanks designed for that purpose.

4. The ether soluble materials containing oxygen, the saponifiable vegetable and animal fats and oils, were digested as readily at 85° as at 120° F. The digested sludge from both processes contained about 13 per cent ether solubles, with only 10 per cent of this total being saponifiable. The remaining amount was indigestible mineral oil.

5. Charging of a digestion tank with a full load of primary tank skimmings was successfully carried out over a 4-month experimental period. The 81 per cent saponifiable fraction of the 74 per cent of ether solubles in this material was reduced successfully to the levels found in normally charged tanks. No benefit to filtration resulted from this practice.

6. No industrial wastes or other material affecting either digestion or filtration have been discovered at this plant.

7. The method of mixing had little effect on the course of digestion if adequate mixing was achieved. However, recirculation pumps did tend to reduce sludge particle size more than the draft tube mixers.

8. Digestion within the 85° to 100° F. levels, considered as optimum by previous workers, showed little significant difference. The advantages of 85° F. operation were such that the slight increase in efficiency at 100° F. was overshadowed.

9. An increase in the digestion temperature to 120° F. produced a profound effect on the characteristics of the sludge and introduced no great operating problems. The advantages of 120° F. operation far outweighed its disadvantages.

10. The 120° F. culture, when once established, was quite stable and resistant to upset. Temperature drops of 9° F. in 48 hr. produced no unusual changes and prolonged holding at lower temperatures showed only a shift back to the 85° to 100° F. organisms. An established culture at any temperature within the range studied produced about the same degree of digestion for the same loading rate.

11. The 120° F. digestion produced a culture quite different from the normal mesophilic organisms and the bacteria in the new culture might play a major part in the improved filterability of the 120° F. sludge.

12. By increasing the digestion temperature to 120° F. the solids passing a 200-mesh screen were reduced from 80 to 65 per cent and sludge filterability was improved several fold.

13. Filtration and general dewaterability by bed drying or other means was apparently a function of digestion and digestion temperature, in addition to the usual parameter; so studies covering this should also be included in any design study.

14. The 120° F. digested sludge solids were low in nitrogen, but the gas was high in methane. Increased protein digestion was the cause of this.

15. The 120° F. process should continue in operational use, but it should be blended with 85° F. sludge to improve the nitrogen content of the fertilizer.

16. Although digestion in the 120° F. or low thermophilic range proved to be a good operating process and substantially solved the solids filtration problem, a good deal of additional research is indicated.

Acknowledgments

The author wishes to acknowledge the valuable help and suggestions of H. A. Tow, Deputy City Engineer, Santa Barbara, Calif.; Ralph Stone, Engineer, Fluor Corp., Los Angeles; and the following staff members of the Hyperion treatment plant, Los Angeles, Calif.: G. A. Parkes, Chief Engineer; R. D. Bargman, Assistant Chief Engineer; J. M. Betz, Civil Engineer; and J. Nagano, Chief Chemist.

References

1. Rawn, A M, Banta, A. P., and Pomeroy, R., "Multiple-Stage Sewage Sludge Digestion." Table 5, p. 101. *Trans. Amer. Soc. Civil Eng.*, **104**, 93 (1939).
2. Imhoff, K., and Fair, G. M., "Sewage Treatment." P. 196. John Wiley & Sons, New York, N. Y. (1940).
3. Metcalf, L., and Eddy, H. P., "Sewerage and Sewage Disposal." Pp. 473–4. McGraw-Hill, New York, N. Y. (1930).
4. Fair, G. M., and Moore, E. W., "Observations on the Digestion of a Sewage Sludge over a Wide Range of Temperatures." *Sewage Works Jour.*, **9**, 1, 3 (Jan., 1937).
5. Fair, G. M., and Moore, E. W., "Time and Rate of Sludge Digestion, and Their Variation with Temperature." *Sewage Works Jour.*, **6**, 1, 3 (Jan., 1934).
6. "Thermophilic Digestion." Editorial, *Sewage Works Jour.*, **3**, 1, 125 (Jan., 1931).
7. Heukelekian, H., and Kaplovsky, A. J., "Effect of Change of Temperature on Thermophilic Digestion." *Sewage Works Jour.*, **20**, 5, 806 (Sept., 1948).
8. Heukelekian, H., "Certain Environmental Conditions Affecting the Value of Thermophilic Seed Sludge." *Sewage Works Jour.*, **4**, 6, 986 (Nov., 1932).
9. Hyde, C. G., "Thermophilic Digestion of Municipal Garbage and Sewage Sludge, with Analogies." *Sewage Works Jour.*, **4**, 6, 993 (Nov., 1932).
10. Fischer, A. J., and Greene, R. A., "Plant-Scale Tests on Thermophilic Digestion." *Sewage Works Jour.*, **17**, 4, 718 (July, 1945).
11. Imhoff, K., "The Continuous-Flow Principle in Sewage Treatment." *Sewage Works Jour.*, **20**, 4, 626 (July, 1948).
12. Rankin, R. S., "High-Rate Digestion of Concentrated Primary and Activated Sludge—Discussion." THIS JOURNAL, **26**, 4, 494 (Apr., 1954).
13. Torpey, W. N., and Lang, M., "Elutriation as a Substitute for Secondary Digestion." THIS JOURNAL, **24**, 7, 813 (July, 1952).
14. Metcalf and Eddy, "Report to Los Angeles City, Bureau of Sanitation." (Jan. 9, 1953.)

A SIMPLIFIED TECHNIC FOR ATMOSPHERIC H_2S STUDIES *

By Gerson Chanin, John R. Elwood, and Edward H. Chow

Chief Sanitary Chemist, Junior Sanitary Engineer, and Senior Sanitary Chemist, respectively, East Bay Municipal Utility District, Sewage Disposal Division, Oakland, Calif.

It is often necessary to evaluate a local or area-wide nuisance problem resulting directly or indirectly from the collection, treatment, and/or disposal of sewage and industrial wastes. A comparatively fast, reliable, sensitive, simple, and reproducible semi-quantitative method for accomplishing this evaluation has been developed by the authors. In essence, the method consists of exposing specially prepared lead acetate test tiles to the atmosphere in question and following the degree of blackening of the tiles, which, of course, is proportional to the amount of hydrogen sulfide in the air being tested.

Some specific examples of actual applications of the technic described are as follows:

1. For a great many years an omnipresent, nauseating, obnoxious odor prevailed along some 21 mi. of the San Francisco Bay shorefront in the East Bay Area (1). This odor was the result of the long-standing procedure of discharging the untreated sewage from the several cities in this area into the tidelands of the bay. More than 30 of such outfall sewers discharged their contents somewhere between high- and low-water lines, thus on low tide depositing sewage solids on dry land; subsequent anaerobic decomposition of this material liberated significant quantities of hydrogen sulfide to the atmosphere. In November 1951 the East Bay Municipal Utility District placed in operation a $23,500,000 sewage treatment plant and intercepting sewer system designed primarily to eliminate this odor problem. Great progress has been made towards that end, the course of which has been and still is being followed by the use of the "bird cage tester" to be described (2).

2. At smaller pumping stations, particularly those located in residential areas where local sewers may have only little slope or where there is a long run to the pump station, the incoming sewage may be septic and liberate H_2S to the atmosphere by way of the ventilation exhaust system. In such cases odor complaints may be anticipated and the extent of the problem evaluated by means of the method to be described.

3. The efficiency of an activated carbon filter installed in an exhaust duct from such a pump station to remove the odors of stale sewage was followed by the use of these H_2S test tiles.

4. Where odor control measures were employed at the treatment plant the results obtained have been followed by means of such test tiles.

5. Where H_2S was suspected as a constituent in an air pollution problem involving the sewerage system these test tiles have proved useful in localizing the point sources, giving at the same time semi-quantitative information as to the magnitude of the pollution problem.

6. Such test tiles would be ideal in evaluating the progress made in an air pollution or nuisance abatement program, where H_2S is involved.

* Presented at 26th Annual Meeting, California Sewage and Industrial Wastes Assn.; Sacramento, Calif.; May 5–8, 1954.

Although the use made of these test tiles by the authors had been limited primarily to applications in the field of sewage treatment, their wider application to other problems can be readily surmised.

Method

At the time these studies were begun, methods available for detecting and measuring the H_2S in an atmosphere were many and ran from the collection of air samples by bubblers with subsequent quantitative chemical analysis to the use of qualitative filter papers saturated with lead acetate (3). All of these methods, however, had limitations to their use for a widespread H_2S odor-nuisance air pollution study. The chemical methods were time consuming and provided information only as to the conditions at the actual time of sampling. In addition, the amounts of sulfide in the atmospheres being dealt with were low (generally less than 0.5 p.p.m. and often much less than 0.1 p.p.m. by volume) and very large volumes of air would have to be sampled through the bubblers to give positive tests. Lead acetate test papers were somewhat better in that they afforded longer contact periods with the suspected atmospheres; however, they were not rugged enough for outdoor use. The solution used to saturate the filter papers generally contains 10 g. lead acetate dissolved in 100 ml. of distilled water containing 5 ml. of glacial acetic acid (4).

To overcome some of the difficulties experienced with the use of lead acetate filter papers, the following test tiles were devised. Strips of unglazed porcelain tiles ("bisque") approximately 4 in. long, ½ in. wide and 5/16 in. thick were employed. These tile strips may be the unglazed liners generally used along the top or bottom of tile walls. A hole was drilled at the top of each tile (Figure 1). These tiles were then immersed in the following solution and allowed to dry at room temperature:

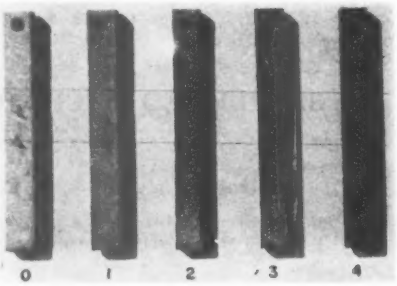


FIGURE 1.—A set of lead acetate test tiles, showing the different degrees of darkening brought about by exposure to an atmosphere containing H_2S.

Distilled water	550 ml.
Glacial acetic acid, A.C.S.	100 ml.
$Pb(C_2H_3O_2)_2 \cdot 3H_2O$, cp	450 g.
Glycerine, A.C.S.	350 ml.

Acetic acid was used in the solution so that large amounts of lead acetate could be dissolved; in this way the dried tile surface would contain a large amount of lead acetate. Glycerine was used to draw and hold moisture on the tiles, since moisture is necessary for the reaction between the H_2S and the lead acetate. It was expected that these changes in the saturating solution would result in increasing the sensitivity of the tests. Permanent records can be obtained by spraying the surface of the tiles with a clear acrylic plastic after exposure to the test atmosphere.

To protect the tiles from the action of rain, etc., openings were cut in No. 10 cans (Figure 2) and the tiles suspended from a bent nail inside the can. The cans were dubbed "bird cage testers" by a local newspaperman because of their resemblance to such cages.

Both test papers and test tiles were employed by the senior author in an area-wide H_2S air pollution study performed by the California Department of Public Health (5). The results of that survey confirmed the prediction

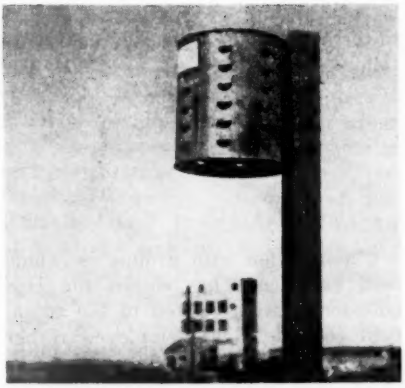


FIGURE 2.—A "bird cage tester" in place at one of the test locations. The test tile is suspended from a bent nail in the can.

that the test tiles would prove to be extremely sensitive. During the entire time of that particular survey no H_2S odors were detectable by the sense of smell, which can detect 0.34 p.p.m., or perhaps less, of H_2S in an atmosphere (6). Yet when the tiles were examined, positive tests for H_2S were obtained in the atmospheres at those locations where for one reason or other its presence might have been expected.

Tests have been run more recently to determine quantitatively the sensitivity of the test tiles, and although this testing is not yet completed all indications are that the test tiles will give positive tests when placed in contact with concentrations of H_2S in air well below 0.1 p.p.m. by volume.

It would seem entirely possible to prepare standard tiles—that is, tiles darkened by exposure to known amounts of H_2S—and by comparison with these standards to make the test more quantitative. This has not yet been tried.

The use of the test tiles in the field may be described as follows: Tiles are prepared as previously described. Sampling stations for location of the test cans are chosen so as to cover completely the area under consideration, particularly any suspect locations. The test cans are hung up, either on poles or on fences, about 6 to 8 ft. from the ground so as to measure ground-level concentrations; or as conditions may demand, suspended in some other manner in the suspected atmospheres. Tiles are then placed within the cans and observations are begun. When such cans must be used in populated areas, labels should be attached to the cans to indicate both the poisonous nature of the lead acetate tiles and to discourage removal or damage of the test cans.

The frequency of observations and the duration of the tests will depend on the particular situation. Generally, in an area-wide hydrogen sulfide odor survey, where the H_2S concentrations are low, examination of the tiles twice each day is adequate. The examination consists of removing the tile from the can and comparing the test tile with an unexposed tile. The degree of darkening, if any, of the tile is reported as 0, 1, 2, 3, or 4, as shown in Figure 1. If the tile has blackened completely it is replaced with a fresh tile. If only slightly darkened, the tile is left in place to see if further darkening occurs. When no further darkening occurs the tile is replaced. A record is kept of the times of examination, the degree of darkening, and the dates at which fresh tiles were set up. This essentially was the method used in the East Bay Municipal Utility District's area-wide H_2S odor survey (2).

If a sump room or other enclosure is to be tested the tile may be placed in the room or in the duct work of the ventilation system, in which case the tile will have to be examined much more frequently, every half-hour or less.

Calculation of "H_2S Odor-Score"

In any case, for the information to be truly valuable, quantitative or semi-quantitative results would be necessary in addition to the qualitative knowledge that H_2S is present or absent.

The following scheme was devised in order to obtain some sort of semi-quantitative number which could be used to compare results from time to time. At the end of a survey the data sheets showing the degree of darkening were collected and analyzed separately for each station.

A typical set of such data as taken from an area-wide survey of H_2S odors in the East Bay area (2) would appear as in Table I, from which the following figures are obtained.

TABLE I.—Typical Tile Observations at Station 25

Date	Observation[1] AM	PM
6/2/53	NT	1
6/4/53	1-NT	NC
6/5/53	1	2
6/8/53	4-NT	NC
6/9/53	2-NT	NC
6/10/53	2	2
6/11/53	3-NT	NC
6/12/53	2	2
6/15/53	4-NT	1
6/16/53	3-NT	NC
6/18/53	2	—

[1] NT = new tile; NC = no change.

Number of new tiles put up..... 6
Number of times tiles changed to No. 1.... 3
Number of times tiles changed to No. 2.... 5
Number of times tiles changed to No. 3.... 2
Number of times tiles changed to No. 4.... 2

By multiplying the number of times the tiles changed the degree of each change and totaling the values so obtained gives a value called the "H_2S odor-score." This score takes into consideration both the degree of blackening of the tiles and the frequency of the blackening; or, in other words, the intensity and frequency of the H_2S odor problem. For the illustrative case this would be obtained as follows:

$1 \times 3 = 3$
$2 \times 5 = 10$
$3 \times 2 = 6$
$4 \times 2 = 8$

Total = 27 = H_2S odor-score

For further simplification and classification the H_2S odor-scores may then be placed into groups corresponding to the symbols used on Figures 3-8, as follows:

H_2S Odor-Score	Group
0- 1	I
2- 6	II
7- 15	III
16- 29	IV
30-110+	V

Classification into groups in which field experience has shown the H_2S odor-scores were related to the actual field conditions was employed rather than the use of the H_2S odor-scores themselves, because this would get away from the use of these scores as truly quantitative figures, which they are not. A score of 30 does not mean that the odor problem is twice as severe as a score of 15. Experience has shown that the H_2S problem is significant only when the score falls into groups III, IV, or V. Generally, H_2S is not detectable by sense of smell when the score is in group III. In group V the H_2S odor is definitely perceptible.

The main advantage of this technic is that no laboratory is required for the performance of the tests. Any sewage plant operator could set up such test cans to detect odors around the plant and to check the area near the plant's effluent discharge to assure himself that such discharge is being accomplished without nuisance.

East Bay Shorefront Surveys

A complete evaluation of the pollution and nuisance abatement obtained as a consequence of the initiation of sewage treatment by the East Bay Municipal Utility District consists of an appraisal of three elements: first, the changes which have occurred in the tideland mudflats; second, the degree of elimination of the odor nuisance; and, third, the changes which have occurred in San Francisco Bay waters. The first and third of these have already been treated in separate reports; the second is discussed herein.

As indicated previously, for many years the residents of the East Bay had been plagued with an omnipresent, extremely disagreeable mudflat stench. It seemed evident that this odor arose as a consequence of disposal of human and industrial sewage and wastes into the shallow waters (mudflats) of San Francisco Bay. It was the elimination of this odor nuisance more than any other factor which led to the formation of Special District No. 1 to collect, treat, and dispose of the sewage and liquid wastes of six East Bay communities. Therefore, the need for a continuing program to evaluate what is being accomplished towards this end was indicated. Such a program was begun by District forces in May of 1952; details of these studies are presented herein.

Results of Field Testing Programs

Before going into the results of the field testing programs it must be emphasized that the presence of slightly darkened tiles or an occasional darkened tile in a test area does not necessarily point to an actual odor nuisance problem, since, as has already been mentioned, the tiles show an accumulative effect and are often positive when no "smell-detectable" H_2S odors are present. The repeated occurrence of highly blackened tiles does point, however, to existence of an odor nuisance in a particular area.

In considering and evaluating the results, wind and weather conditions must be taken into account; a foggy, warm day with little wind seems to be the condition under which maximum effects are obtained. Weather conditions were followed throughout most of these surveys.

It is evident that the large amount of data collected could not all be included in this report. In addition, inclusion of tables of the individual readings would serve no particular purpose, because the results must be evaluated as a whole to be of any significance.

In the evaluation of the accumulated data both the intensity of the blackening and the frequency of the blackening were considered; that is, H_2S odor-scores were determined as previously described.

Discussion of Results

In discussing the results shown on the maps (Figures 3–8), each area is discussed separately at first, then an over-all evaluation is made.

A. The first area considered is that surrounding San Leandro Bay. This was one of the worst areas from both the water and air pollution standpoints. It is in this same area that the greatest amount of sewage and industrial waste pollutants have been removed from the bay waters. At the time of the survey in 1952, large quantities of sewage and industrial waste were still being discharged into San Leandro Bay and this was reflected in the extensive odor problem shown in Figure 3.

By the time the 1953 study was made almost all of this sewage and waste was being intercepted and collected by the East Bay Municipal Utility District system. The generally better conditions resulting are shown by the virtually complete absence of any darkened tiles (Figure 4).

This definitely points out the benefits to be derived from the proper collection, treatment, and disposal of sewage.

B. The situation in the next area considered is more complex. This area roughly parallels the estuary and extends from High Street south to the sewage treatment plant. A first glance at Figures 5 and 6 does not seem to reveal a significant improvement. Nevertheless, although about the same number of stations reveal the presence of H_2S in the atmosphere, the distribution of these stations was different in the two years; and of even greater importance, the intensity of the odor problem was appreciably less in 1953 than in 1952. In 1952, 12 of 13 loca-

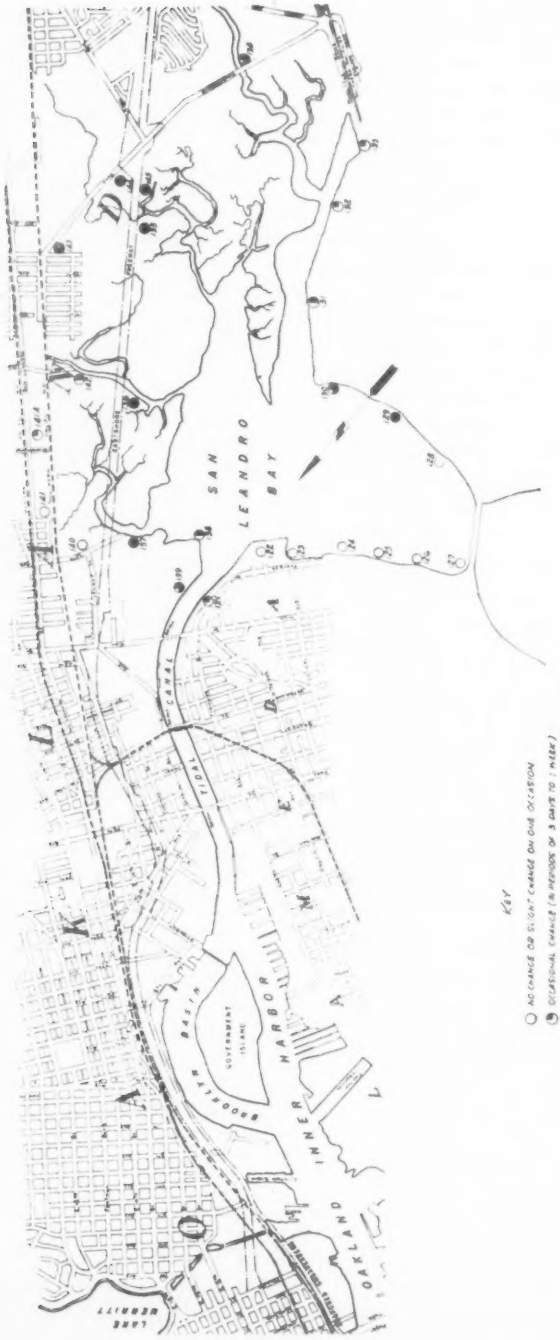


FIGURE 3.—Test results in part of San Francisco Bay odor survey, 1953.

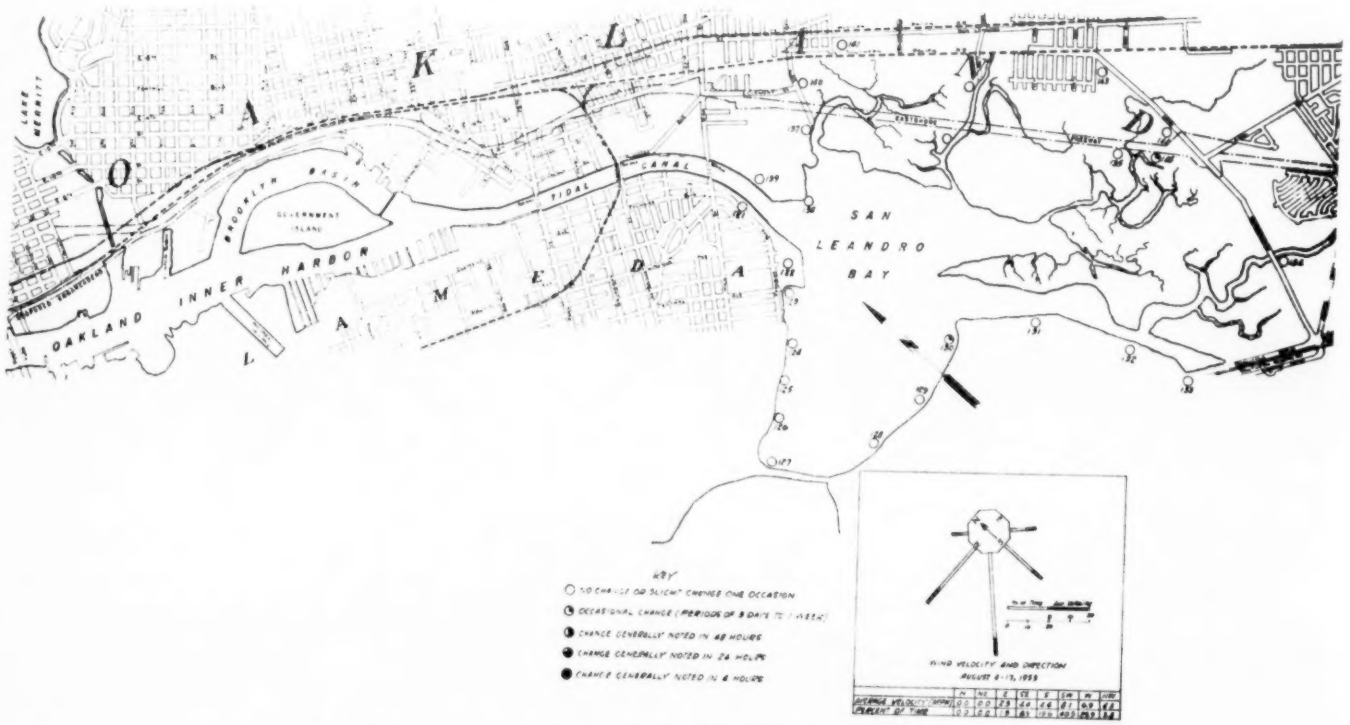


FIGURE 4.—Test results in part of San Francisco Bay odor survey, 1952.

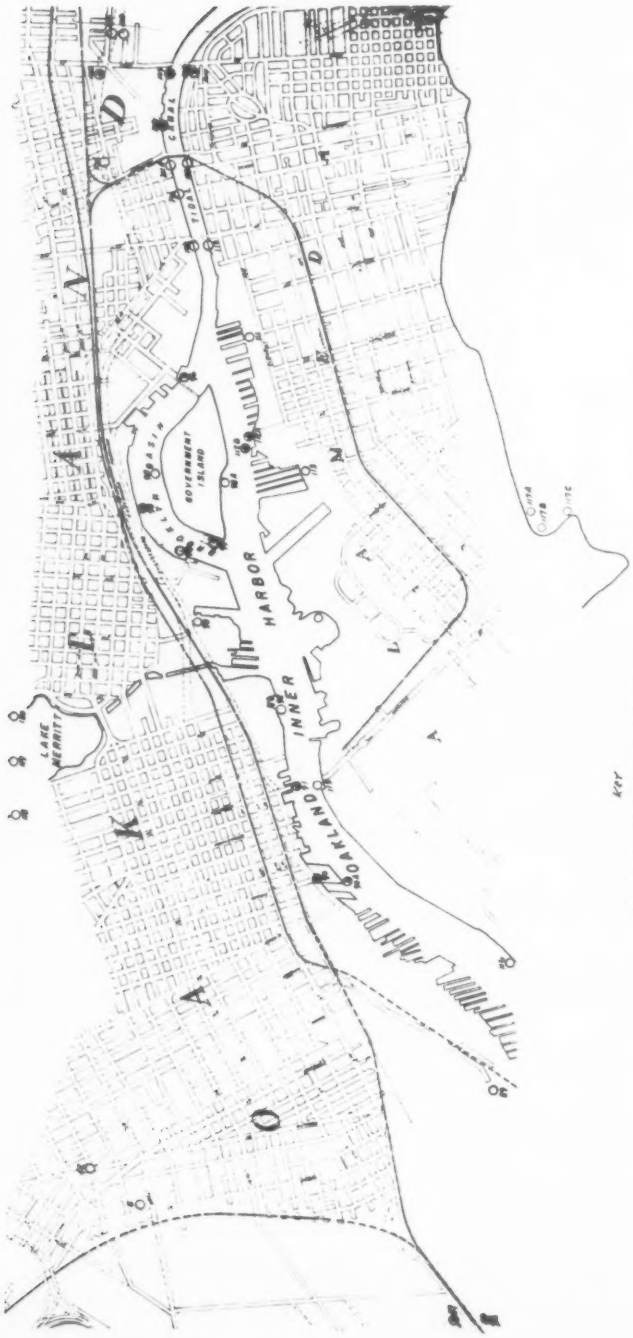


FIGURE 5.—Test results in part of San Francisco Bay odor survey, 1952.

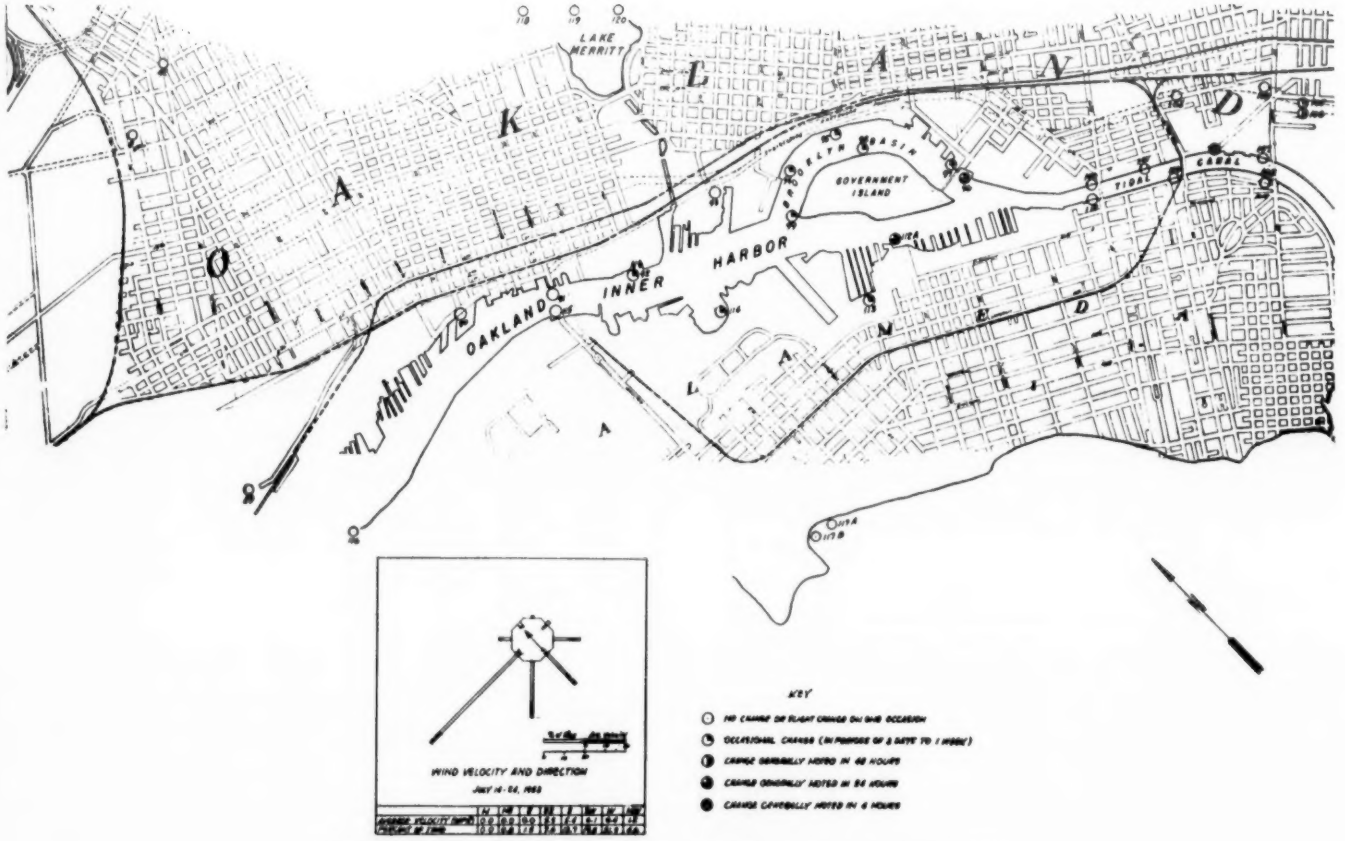


FIGURE 6.—Test results in part of San Francisco Bay odor survey, 1953.

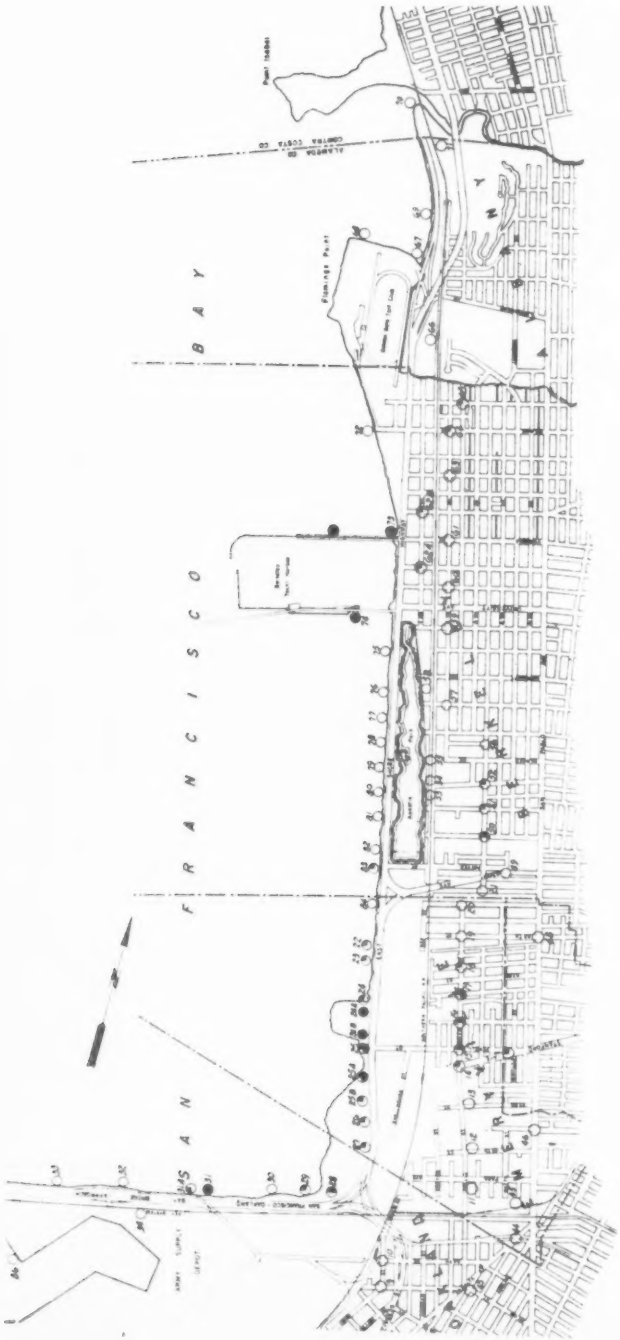


FIGURE 7.—Test results in part of San Francisco Bay odor survey, 1952.

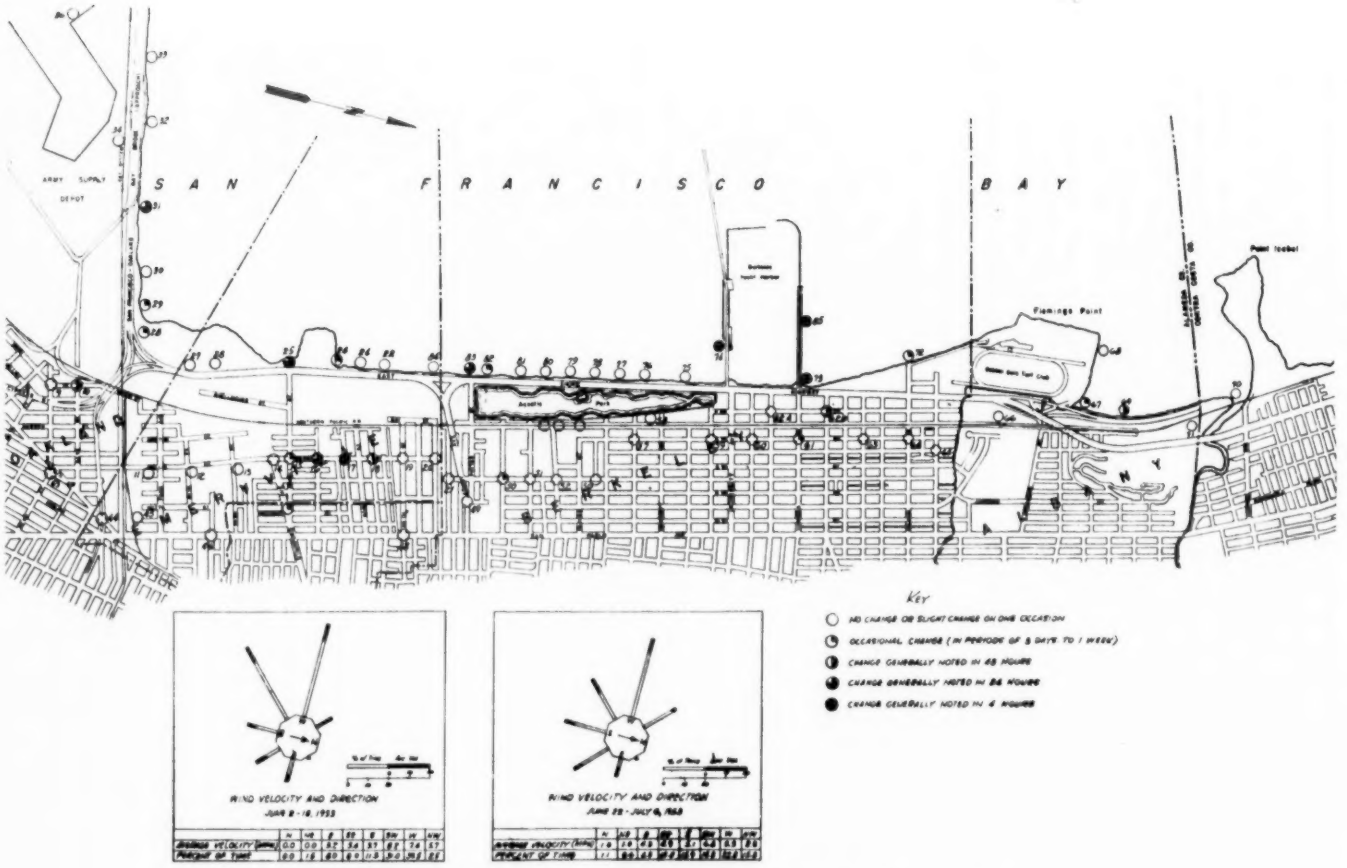

SAN FRANCISCO BAY
ARMY SUPPLY DEPOT
Fleming Point
Key
NO CHANGE OR SLIGHT CHANGE ON ONE OCCASION
OCCASIONAL CHANGE (IN PERIODS OF 5 DAYS TO 1 WEEK)
CHANGE GENERALLY NOTED IN 48 HOURS
CHANGE GENERALLY NOTED IN 24 HOURS
CHANGE GENERALLY NOTED IN 4 HOURS
WIND VELOCITY AND DIRECTION
JUNE 8 - 18, 1953
WIND VELOCITY AND DIRECTION
JUNE 28 - JULY 6, 1953

FIGURE 8.—Test results in part of San Francisco Bay odor survey, 1953.

tions showing positive results had H_2S odor-scores exceeding 7, whereas in 1953 only 4 of 14 locations showing positive tests had scores exceeding 7, and in every one of these cases there was a known reason for the H_2S in the atmosphere.

Generally speaking, at the time of the 1952 study many outfall sewers were still discharging into the estuary from both Alameda and Oakland. Although many of these had been intercepted by the time of the 1953 study, several were still discharging into the estuary.

Keeping this in mind the following observations may be made:

1. The high concentration of atmospheric sulfides shown at stations 107 and 108 in 1952 was completely eliminated when the High Street sewer was connected to the East Bay Municipal Utility District sewer system, and no sulfides were found in those locations in 1953.

2. The Alameda Avenue outfall sewer discharges at station 102. Although this sewer was intercepted, there is still sewage flowing out of the old outfall due to a connection made by error between the City of Oakland's storm and sanitary sewers when the Freeway was built in that area. Therefore, sulfides are still found in that area.

3. The area around Government Island (stations 94, 95, 96, 97, 98, 99, and 112A) still receives sewage discharges from Oakland, Government Island, and Alameda. However, the amount of sewage discharged in this area was much less in 1953 than in 1952. Although sulfides were found in this area, in 1953 they were generally low except near the outfall sewers themselves. The Oakland Dennison Street sewer still discharges at station 96. The Alameda Grand Street storm sewer, which receives sewage from federal housing projects, still discharges at 112A and 112B. The Coast Guard sewer on Government Island still discharges along the northeast side of the island.

4. Sulfides were not found at station 90 or 91 in 1953, as they were in 1952, because the Oakland Grove Street and Webster Street sewers were connected to the East Bay Municipal Utility District system.

5. Sulfides were found both in 1952 and 1953 at station 87, which is located near the still discharging 7th Street Oakland outfall sewer.

6. The small amount of sulfide found at stations 92 and 114 may reflect discharges of sewage from the Encinal outfall sewer in Alameda.

7. Sulfide gases may reach the atmosphere from sources other than sewage sludge beds and septic waters. A used oil reclaiming plant is located at station 103. In 1952 sulfide was generally found in the atmosphere near the plant. In 1953, although tests at station 103 were negative, positive tests were obtained at stations 105 and 106. Although there are other gas waste producing industries in that immediate area, it seemed more likely that the blackening at these stations was caused by sulfide-containing air from the oil reclamation operation. The wind chart shown in Figure 6 would tend to indicate that such was not the case. However, these wind data are based on an anemometer installed at the sewage treatment plant and may not always show the same wind directions as the winds in the eastern part of Oakland. Therefore, a special study was made at this area, from which it was concluded that the H_2S found in the atmosphere in the areas surrounding High and East 8th Streets was generally traceable to the oil reclaiming operation.

8. Negative stations located along the south shores of Alameda indicate that no sulfide arises from San Francisco Bay waters in that area.

C. The last area to be considered also presents a more complex problem. Roughly, this area extends from the

sewage treatment plant northerly to Point Isabel just inside Contra Costa County, paralleling the shore front. Once again, a first glance at the maps of this area (Figures 7 and 8) does not seem to show any significant change in conditions. Here too, however, a more thorough analysis reveals a trend towards the elimination of the problem. In this area there are still varying amounts of sewage and industrial wastes being discharged into the tidal waters. Therefore, any evaluation made must take all factors into account. With this in mind the following observations may be made:

1. Taking the entire north shore area as a whole, in 1952, 32 of the 75 (or 43 per cent) of the test locations showed the presence of H_2S in the atmosphere; in 1953 this was reduced to 22 of the 73 (or 30 per cent) of the locations tested.

2. The area north to Ashby Avenue has been for a long time the worst area from the H_2S odor nuisance standpoint. There has been little or no change between the 1952 and 1953 contributions of sewage to the tidal waters; yet a generally better condition was found in 1953 than in 1952. In 1952 blackened tiles were found at 21 of 38 (or 55 per cent) of the test stations. In 1953 this was reduced to 11 of 33 (or 33 per cent). The only explanation for this is the generally higher dissolved oxygen content of the bay waters in 1953; this oxygen acts to oxidize all or a part of the sulfide liberated from the muds.

3. The blackened tiles along Hollis Street in Emeryville and extending into Berkeley along 7th Street do not reflect sulfides from the bay or mudflats; instead they result from gaseous industrial waste discharges to the atmosphere. This is especially evident in the 1953 results when, despite the predominantly on-shore winds, tiles placed along Hollis Street darkened more than those placed along the shorefront. This is the reverse of what might be expected had the H_2S arisen from the tidal mudflats. In fact, tests actually indicated that some of the darkening of the tiles along the shorefront came about when there were off-shore winds.

4. Outfall sewers still discharging in this area are located in the vicinity of stations 23, 24, 25, 27, and 31, accounting for the positive H_2S tests at these stations.

5. At times, when the weather is warm and moist and the tide low, the old "stench" is still noticeable in the area from Ashby Avenue to the Bay Bridge approaches. However, the occurrence of these smells is much less frequent and their intensity is very low as compared to that previously "endured" by all commuters.

6. Although almost all the major sanitary sewers in Berkeley have been intercepted and are flowing to the East Bay Municipal Utility District's sewage treatment plant, there is still a significant flow of sanitary sewage out of the old combined outfall sewers. Therefore, although the amount of sewage reaching the bay has been lessened, H_2S is still being generated in the vicinity of the outfall sewers as a result of the continuing discharge of sanitary wastes. Outfall sewers are located at stations 83, 74, 85, 72, and 67.

7. The higher sulfide almost always found in the air around stations 85 and 73 may only in part be a consequence of the discharge of sewage. At times, it seemed evident that a part of the H_2S arose from the Berkeley dump. This would be a possibility were anaerobic digestion of garbage allowed to set in.

8. There is an apparent anomaly at stations 72, 67, and 69. At these locations no atmospheric H_2S was detected in 1952, whereas sulfide in low concentrations was found in 1953. The waters at these stations are still receiving raw sewage and the presence of sulfide in the air is not unexpected. The cove

between Golden Gate Fields and Point Isabel receives the raw sewage from the Buchanan Street sewer and from the Stege Sanitary District. The fact that during the 1952 survey H_2S odors were not detectable by smell, whereas in 1953 definite H_2S odors were observed on several occasions, may be explained by the construction of the new Stege Sanitary District sewage treatment plant, which made it necessary to divert the raw untreated sewage from that District's outfall sewer on Point Isabel and to discharge it closer on-shore, where the lack of oxygen-bearing dilution water resulted in a worse odor problem.

Summary

A relatively simple method for atmospheric H_2S pollution studies has been described which permits sampling of a large area in a short time with a minimum of manpower and equipment. Some specific applications of the technic are described.

References

1. Hyde, C. G., Gray, H. F., and Rawn, A M, "Report Upon the Collection, Treatment and Disposal of Sewage and Industrial Wastes of the East Bay Cities, California." Unpublished report (June 30, 1941); abs. *Sewage Works Jour.*, **14**, 1, 234 (Jan., 1942).
2. Chanin, G., "Atmospheric Hydrogen Sulfide Pollution Problem." Unpublished report.
3. Jacobs, M. B., "The Analytical Chemistry of Industrial Poisons, Hazards, and Solvents." 2nd Edition 1949, Interscience Publishers, Inc. Chapter IX.
4. Jacobs, M. B., "The Analytical Chemistry of Industrial Poisons, Hazards, and Solvents." 2nd Ed., p. 320. Interscience Publishers, Inc. (1949).
5. "A Survey of Possible Pollution and Nuisance Existing in the Vicinity of the Orange County Joint Outfall Sewer." Unpublished report, State of California Department of Public Health (1951).
6. "Hydrogen Sulfide, Its Toxicity and Potential Dangers." (Reprint No. 2256 from *Pub. Health Rep.*) *Pub. Health Rep.*, **56**, 684 (1941).

METAL–FINISHING WASTES ANALYSIS GUIDE

Procedures for analyzing metal-finishing wastes are outlined in a new manual published by the Ohio River Valley Water Sanitation Commission in cooperation with its Metal-Finishing Industry Action Committee. The procedures represent an endeavor to provide methods that will screen out substances which cause interference in the use of commonly accepted analytical techniques.

The 108-page report details 19 methods recommended by the Metal-Finishing Industry Action Committee of the Commission following three years of intensive field testing of procedures developed at Lehigh University, where the American Electroplaters' Society has been sponsoring related projects on analytical work. The field testing was carried out by member companies of the metal-finishing and other industry committees of the Commission, as well as by the eight state regulatory agencies represented on the Commission.

Copies of the report, priced at $1.00, may be obtained from the Commission, 414 Walnut Street, Cincinnati 2, Ohio.

Industrial Wastes

OXIDATION OF ENZYME DESIZE AND STARCH RINSE TEXTILE WASTES

By Nelson L. Nemerow

Department of Civil Engineering, University of North Carolina, Raleigh, N. C.

Textile industries produce a low unit cost product. Therefore, any expenditure of money for a process change or waste treatment will most likely be postponed until such time as either (a) more economical methods for waste treatment are available or (b) the industry is forced by a delegated agency to reduce its waste load. At present little waste treatment is practiced by the textile industry. Most of the methods available and tried are those used by sewage treatment plants for domestic wastes. Textile wastes, being both more pollutional and of a different character, do not respond exactly the way domestic wastes do to the accepted sewage treatment processes. It remains, then, for the researcher to investigate new treatment methods that might be more economical.

The purpose of this study, therefore, was to determine the quantity and sanitary characteristics of the wastes arising from the desizing of cotton fibers. In addition, oxidation of these wastes in the presence of adapted microorganisms was investigated as a possible treatment method.

Processes Producing Wastes

In order for cotton yarns to be woven into goods for sale they must first be "sized" or coated with a solution usually consisting of tallow, starch, clay, and other fillers so that it can be woven more easily. The yarn, once woven, is called grey goods.

Before bleaching and dyeing, however, all sizing must be removed from the cloth. Most modern processes for desizing are usually carried out by means of enzyme solutions.

The grey goods are passed through a typical desize solution consisting of 28 lb. of Exsize T, 12 lb. of Triton 100, and 800 gal. of water. The wetted treated material is stored in bins for a minimum of 1½ hr. to allow the enzymic action to proceed. The waste enzyme solution is discharged at the end of each 24 hr. This is the source of the first waste in the desizing process.

The goods are then passed through washers where the converted starch (inverted sugar) is rinsed off. The overflow rinse waters are the second and final wastes arising from the desizing process.

Review of Literature

Geyer and Perry (1) discuss these wastes and state that waste desizing baths are highly polluted and should be classed with deterging wastes. They are not large in volume. They also state than an average desize waste, where malt diastase is used, would have about 11,800 p.p.m. total solids, 6,850 p.p.m. of 1-day B.O.D., and a pH of 5.5 to 7.0. The New England Interstate Water Pollution Control Commission (2) mentions that the diverse methods of desizing lead to waste characteristics of some variety. If sizing is removed in the kier, it is not considered a desize waste, but is included with the waste kier liquor. The desizing bath waste may have a B.O.D.

of from 6,500 to 8,000 p.p.m. and its wash waters from 200 to 1,800 p.p.m., but its volume is variable and small. Bath and wash-water wastes average around 110 gal. per 100 lb. of goods, show a B.O.D. of approximately 1,750 p.p.m., and a population equivalent of 9.6 persons per 100 lb. of goods.

Burford, Berger, and Masselli (3) proclaimed that all desizing wastes, with the exception of some of the final water rinses, exhibit high biochemical oxygen demands, but almost all are neutral. They concluded that although the desizing waste has a B.O.D. of 1,748 p.p.m., a very small quantity is dumped at infrequent intervals and therefore a negligible load is added to the stream. Catlett (4) reports as a typical practice the padding down of the goods with a mixture of 10 qt. of Rapidose (a commercial diastase) with 200 gal. of water. He also gives typical analyses of these wastes from many representative samples. Another reference (5) gives the B.O.D. of the desizing bath as greater than 8,000 p.p.m., although the volume is reported to be small. The volume of wash water varies with individual mills, but it is equivalent to a sewered population of approximately 96 persons per 1,000 lb. of goods per day. The following results are reported as typical:

Waste	Flow (gal.)[1]	B.O.D. (p.p.m.)	Pop. Equiv.[2]
Desizing bath	140	8,000	54
Wash waters	200–1,800	840	42
Total	1,100	1,750	96

[1] Per 1,000 lb. goods.
[2] Per 1,000 lb. goods per day.

Burford and Masselli (6) conducted surveys which showed that only 20 to 30 per cent of the B.O.D. pollution load from cotton mills is caused by the natural compounds in the cotton fiber. These are removed in the kiering processes and discharged in the kier wastes. The remaining 70 to 80 per cent of the B.O.D. is contributed by the processing chemicals in finishing the cloth. Of these, starch and its modifications are the greatest single source of B.O.D. The main waste containing starch and its modifications contributing to the total B.O.D. load are desize wastes (35 per cent). In the desize waste the starch is almost entirely converted to glucose. After adding up all the pollutional starch or starch degradation products, it was concluded that starch wastes contribute almost 50 per cent of the total B.O.D. produced by an en-

TABLE I.—Quantity and Sanitary Characteristics of Enzyme Desize and Starch Rinse Wastes

Item	Enzyme Desize	Starch Rinse
Volume (gal./100 lb. goods)	2.5	720
pH	7.35	7.1
B.O.D., 5-day (p.p.m.)	4,375–5,063	997
Total solids (p.p.m.)	8,946–10,548	1,482–1,830
Total vol. solids (p.p.m.)	5,540–6,952	1,232–1,532
Total ash solids (p.p.m.)	2,939–3,596	226–306
Suspended solids (p.p.m.)	197–272	244–268
Suspended vol. solids (p.p.m.)	168–189	232–252
Suspended ash solids (p.p.m.)	8–96	8–24
Total diss. solids (p.p.m.)	8,682–10,276	1,238–1,562
Dissolved vol. solids (p.p.m.)	5,372–6,745	996–1,280
Dissolved ash solids (p.p.m.)	2,931–3,984	182–242
Total alk., as $CaCO_3$ (p.p.m.)	176	24
Total org. nitrogen (p.p.m.)	—	11
Chloride, as Cl (p.p.m.)	—	21
Sulphate, as SO_4 (p.p.m.)	—	5
Color[1] (p.p.m.)	400	80
Turbidity, Jackson (p.p.m.)	—	250

[1] Standard color wheel.

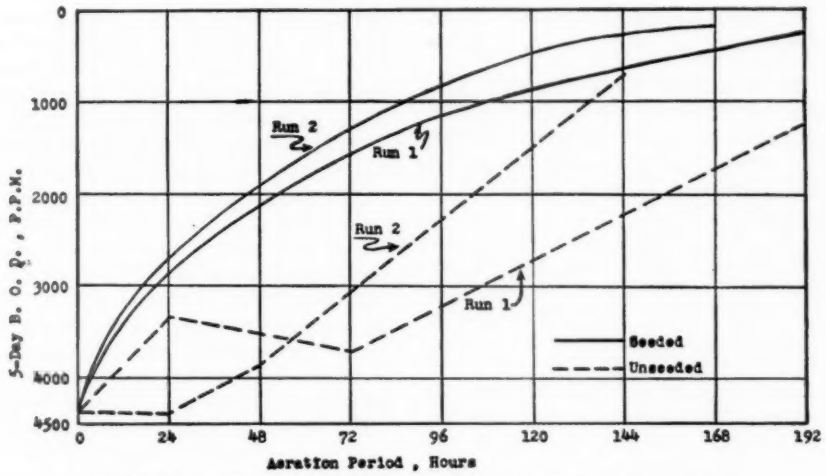


FIGURE 1.—Effect of aeration on B.O.D. of enzyme desize waste.

tire cotton mill. It was suggested that carboxymethyl cellulose be substituted for starch by the cotton mill rather than to attempt to treat starch wastes. This recommendation has much merit, but it has not been put into practice to any significant degree.

Experimental Procedure

The investigation was carried out in two parts, as follows:

1. The determination of the volumes and sanitary characteristics of the wastes.

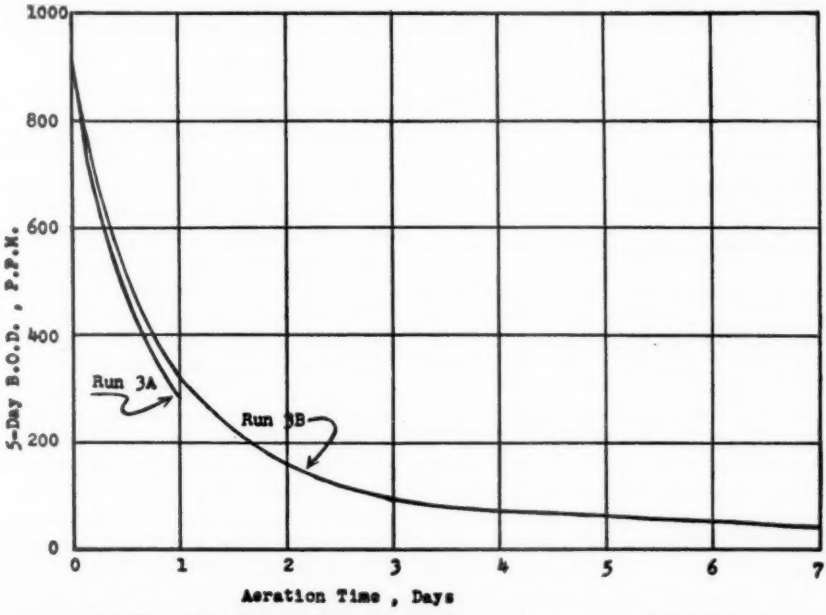


FIGURE 2.—Effect of aeration on B.O.D. of desize and starch rinse wastes.

2. Oxidation of the wastes in the presence of adapted microorganisms.

To accomplish the first, several samples of both wastes were taken from a typical mill, the analyses and volumes per unit of product were determined and averaged. The results are presented in Table I.

To accomplish the second part of the investigation, three separate experimental runs were carried out. The first and second runs used adapted seed material to oxidize the enzyme desize waste. Aeration of the desize waste without any added seed was used as the control in these two experiments. Aeration was carried out for a total of 192 hr. At various intervals during this period the aeration was momentarily stopped, the solids were permitted to settle out of the mixtures, and samples of the supernatant fluid were withdrawn for analysis for the remaining B.O.D. The results of these two runs are presented in Figure 1. In the third run a mixture, in the appropriate proportions of desize and starch rinse wastes was aerated for 7 days in the presence of previously adapted seed material. Samples of the settled supernatant were taken after 1, 3, and 7 days of aeration. Duplicate 1-day aeration columns were set up to verify the total oxidation that occurred in 24 hr. The results are presented in Figure 2.

Discussion of Results

For every 100 lb. of goods processed by a finishing mill there are discharged 720 gal. of starch rinse-water waste and only 2.5 gal. of enzyme desize waste. However, a gallon of the desize waste is about five times as pollutional (with a 5-day B.O.D. of 5,000 p.p.m.) as a gallon of starch waste (with a B.O.D. close to 1,000 p.p.m.) Both wastes are highly dissolved and predominately organic in nature. The enzyme waste is highly colored (brown) and is approximately neutral or slightly alkaline in reaction. The starch rinse water is milky in appearance and also neutral in reaction. The starch waste, which is the controlling one in volume and total pounds of B.O.D., has a dissolved organic matter to B.O.D. ratio of slightly greater than 1:1. This latter ratio is also true in the enzyme waste (Table I). Indications are that the dissolved organic matter is of such a nature that it may easily be broken down by bacterial oxidation quite completely in the 5-day period. This ratio is considerably higher for most domestic sewages, indicating that sewage is much more difficult to decompose completely in a 5-day period than are these wastes.

Both experimental runs 1 and 2 showed that by mixing the enzyme desize waste with adapted seed and aerating for 24 hr. the B.O.D. was reduced from about 4,400 to about 2,800 p.p.m., or about 37 per cent (Figure 2). After 48 hr. of aeration the B.O.D. was reduced to about 2,000 p.p.m., or about 55 per cent; after 72 hr. to about 1,400 p.p.m., or 70 per cent; after 144 hr. to about 500 p.p.m., or about 90 per cent; and after 168 hr. to about 200 p.p.m., or about 95 per cent. It is apparent that almost any degree of B.O.D. reduction could be obtained, depending upon the length of time of aeration. The unseeded control samples showed slight and erratic B.O.D. reductions during the first 72 hr. and thereafter the B.O.D. reduction increased steadily, indicating definite oxidation. The over-all reductions in B.O.D. were never as high in the unseeded samples as in the seeded ones. However, it must be remembered that part of the reduction in the latter samples was simply due to dilution with some adapted seed materials. Similar oxidation results were observed when the writer experimented with cotton kiering liquor wastes. It is quite conceivable that some type of auto-oxidation occurs without deliberate seeding after a certain period of time.

In experimental run 3 the oxidation of a mixture of approximately 288 vol-

umes of starch rinse waste to 1 volume of enzyme waste produced a B.O.D. reduction when mixed with adapted seed matter of about 67 per cent from 925 p.p.m. to about 300 p.p.m. in 24 hr. (Figure 2). The settled supernatant when used to seed a fresh sample of the waste mixture produced a similar reduction in B.O.D. after 24 hr. (Figure 2, run 3B). After 72 hr. of aeration the B.O.D. reduction was about 90 per cent, from 925 p.p.m. to about 85 p.p.m. After 7 days of aeration the B.O.D. reduction was about 95 per cent, from 925 p.p.m. to about 40 p.p.m. Once again almost any desired B.O.D. reduction was obtainable, depending upon the length of time of aeration. In other words, a 24-hr. aeration-holding basin would produce partial treatment of 67 per cent reduction, whereas a basin designed to hold and aerate a 3-day volume of waste would produce complete treatment, or 90 per cent B.O.D. reduction. This run illustrated the oxidation of the combined typical waste which would have to be treated by the mill. The results were quite encouraging, as the degree of oxidation was considerably higher than that of the enzyme desize waste.

Conclusions

1. The finishing of 100 lb. of goods effects a combined water waste of 722.5 gal. containing 6.1 lb. of 5-day, 20° C., B.O.D.

2. More than 99 per cent of the volume of the waste arises from the washing of the converted starch from the goods. The remaining small volume is the enzyme desize bath waste. Although this bath has a B.O.D. of about 5,000 p.p.m., its volume is so small that the waste is almost negligible when compared to the starch waste.

3. The wastes are highly dissolved, colored, and predominately organic in nature.

4. Mixing of adapted dispersed seed and oxidation reduced the B.O.D. of the small-volume desize waste 37 per cent in 24 hr.; 53 per cent in 48 hr.; 70 per cent in 72 hr.; 90 per cent in 144 hr.; and 95 per cent in 168 hr.

5. Mixing of adapted dispersed seed and oxidation reduced the B.O.D. of a mixture (of 99+ per cent starch waste and 1 per cent desize waste) 67 per cent in 24 hr.; 90 per cent in 72 hr.; and 95 per cent in 7 days.

References

1. Geyer, J. C., and Perry, W. A., "Textile Waste Treatment and Recovery." Textile Foundation, Washington, D. C. (1936).
2. "Textile Wastes—A Review 1936–1950." Hall Lab. of Chem., Wesleyan Univ., Middletown, Conn.
3. Burford, W. G., Berger, H., and Masselli, J. W., "A Survey of Three Textile Mills in Connecticut." Hall Lab. of Chem., Wesleyan Univ., Middletown, Conn. (May, 1951).
4. "Textile Wastes as Related to Stream Pollution." N. C. State Stream Sanit. and Conserv. Committee, p. 189 (1948).
5. "Ohio River Pollution Control, Supplement D, Industrial Wastes Guide." P. 1112 (1943).
6. Burford, M. G., and Masselli, J. W., "An Analytical and Inventory Survey of Industrial Wastes From a Connecticut Cotton Mill." Hall Lab. of Chem., Wesleyan Univ., Middletown, Conn. (1953).
7. Nemerow, N. L., "Oxidation of Cotton Kier Liquor Wastes." THIS JOURNAL, **25**, 9, 1060 (Sept., 1953).

PILOT-PLANT STUDIES OF REFINERY WASTES TREATMENT ON TRICKLING FILTERS*

By Gordon E. Mau

Chief, Water Pollution Control Section, Division of Sanitation, Kansas State Board of Health, Lawrence, Kans.

A number of papers describing the pollutional characteristics of petroleum refinery waste have been published in recent years. Until recently, however, the industry has focused most of its attention on oil separation and similar waste treatment to remove the nuisance and visible pollutants. Only during recent years have thorough studies on biological treatment of refinery waste been undertaken, although the degrading effects upon streams, caused primarily by an oxygen deficiency, have been apparent for many years. A joint study to obtain design data and definite information on the results to be expected from biological treatment with trickling filters was undertaken at their Coffeyville refinery by the Cooperative Refinery Association and the Division of Sanitation, Kansas State Board of Health.

Refinery Operations

The Coffeyville refinery waste and surface runoff from the refining area, with the exception of the strongest caustic, flows to a two-compartment type A.P.I. oil separator, followed by a small pond, before being discharged to the Verdigris River. A constant portion of waste was taken from this pond effluent for treatment in the pilot plant. The caustic excluded from the stream has an exceptionally high B.O.D. (up to 100,000 p.p.m.), a high phenol concentration, and flows at the rate of 1 to 2 g.p.m.

During February, March, and April 1952, the refinery processed an average of 23,000, 20,200, and 20,700 bbl. of crude oil per day, respectively. The various refining processes include the crude units, gasoline treaters, catalytic cracker, gas concentrator, thermocracker, polymerization, furfural unit, heavy oil treaters, light oil treaters, vacuum distillation, de-waxing, and clay contact. Average daily production during the three months is given in Table I.

TABLE I.—Average Daily Production of the Cooperative Refinery during February, March, and April 1952

Product	Bbl.[1]
Gasoline	9,400
Kerosene	2,600
Light gas oil	1,710
Light cycle stock	1,140
Heavy fuel oil	1,420
Fuel gas	1,200
Sludge	290
Lube	1,140
Lube extract	500
Wax	100
Asphalt	1,500
Total	21,000

[1] 42-gal. barrel.

Raw Waste Characteristics

Domestic sewage was not included in the refinery waste. A complete analysis was not made on all of the 24-hr. composite samples, but based on analyses made over a three-month period, the raw refinery waste had the characteristics indicated in Table II.

* Presented at 1954 Annual Meeting, Kansas Sewage Works Assn.; Emporia, Kans.; Apr. 7–9, 1954.

TABLE II.—Raw Refinery Waste Data

Item	Median	Range
Temperature (°F.)	80	68–88
Dry-weather flow rates (m.g.d.)[1]	2.1	0.5–3.8
Daily waste flow (m.g.d.)[2]	2.15	0.96–>6.69
B.O.D. (p.p.m.)[3]	105	50–>650
B.O.D. (lb./day)[3]	1,720	562–>19,600
Alkalinity (p.p.m.)[3]:		
Phenolphthalein	44	0–104
Total	190	148–250
pH[3]	8.7	8.0–9.5
Turbidity (p.p.m.)[3]	170	95–380
Oil (p.p.m.)[3]	100	42–860
Dissolved oxygen (p.p.m.)[3]	0.0	0–7.3
Chlorides (p.p.m.)[3]	180	145–220

[1] At hourly intervals.
[2] Including surface runoff.
[3] Analyses on 24-hr. composite samples.

pH and alkalinity control analyses at approximately 2-hr. intervals (Table III) showed a maximum total alkalinity of 446 p.p.m. and a maximum phenolphthalein alkalinity of 270 p.p.m.

Sulfides were not considered to be a serious problem in this refinery's waste and therefore regular analyses for sulfide content were not made. Since the slight amount of aeration provided in flocculation usually resulted in some dissolved oxygen being present in the waste, it was concluded that the sulfide concentration would of necessity have to be low.

The 5-day B.O.D. population equivalent averaged 700 per 1,000 bbl. of crude oil and the waste averaged 105 gal. per barrel of crude.

TABLE III.—Raw Waste pH Data, Determinations Made Every Two Hours

pH	No. Times Occurring	% of Total
>10.0	2	0.22
9.6–10.0	22	2.43
9.1– 9.5	107	11.8
8.6– 9.0	732	80.0
8.1– 8.5	38	4.20
7.6– 8.0	1	0.11
7.1– 7.5	—	—
<7.0	4	0.44
Totals	906	100

Description of Pilot Plant

The pilot plant provided 30-min. coagulation and a detention of about 5 hr. in primary settling. The primary basin effluent was applied at different rates to seven different filters, with recirculation ratios varying from 0 to 1.0; raw waste was applied to one filter for a period of 9 days. Sedimentation was provided following each filter, and settled filter effluent was recirculated.

The coagulation facilities consisted of two 55-gal. oil drums arranged in series. Chemicals and raw waste were added through an air gap into the open end of a pipe which extended to the bottom of the first flocculator. Waste flowed from the first flocculator to the second through a connecting pipe at about mid-depth.

Primary sedimentation was provided by means of one 3-ft. by 10-ft. basin with a 2.33-ft. water depth. A sludge drawoff pipe, which could be adjusted to either drain the basin or maintain any water level, was provided at the inlet end. The rate of flow into the basin was about 2.5 g.p.m., but only 1.75 g.p.m. was needed for the operation of the filters. The flow in excess of the filter requirements was allowed to overflow continuously through the sludge drawoff pipe.

The filters were constructed by welding two 55-gal. oil drums end-to-end and supporting them on a steel frame. The filters were each 22.5 in. in diameter, but the rock depth varied so that the individual filter volumes ranged from 13.0 to 13.5 cu. ft. Slots were cut for ventilation purposes in the side near the bottom of each filter cell. A tipping box dosing device (Figure 1) was located above each filter and, to aid further in dosing the filters, a metal plate with holes in it was placed on top of the rock. Good distribution of waste onto the filters was obtained by this means.

The control box (Figure 2) permitted the application of various rates

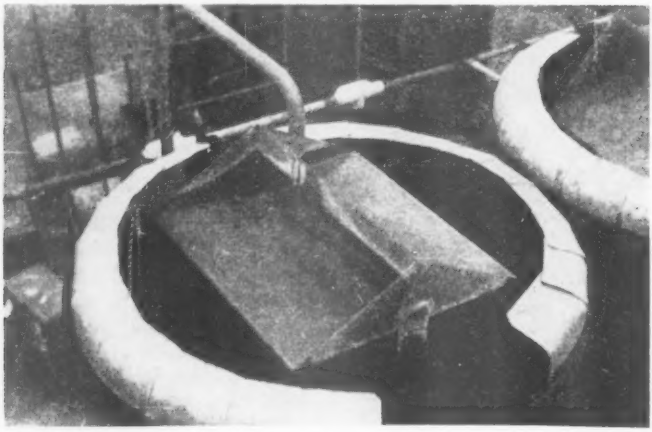


FIGURE 1.—Tipping box dosing device for pilot-plant filters.

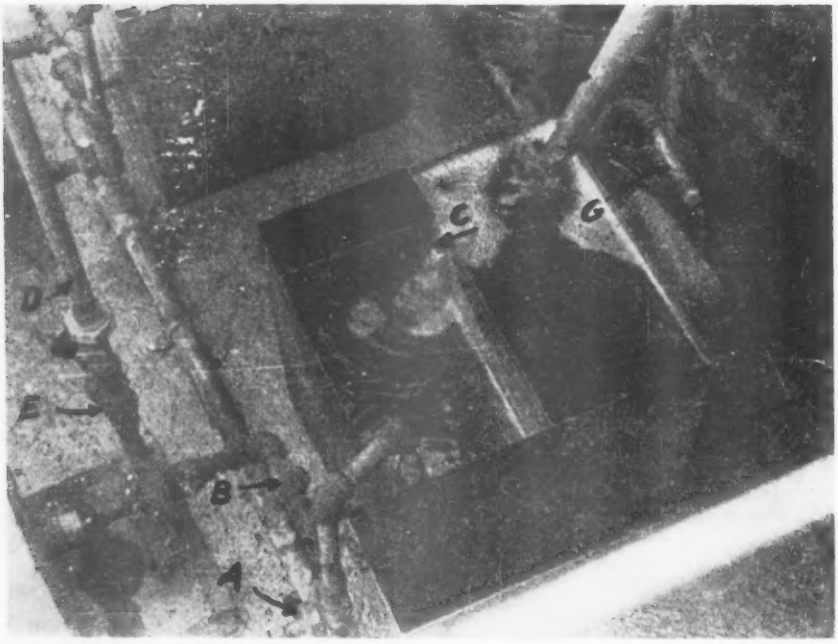


FIGURE 2.—Typical filter control box showing: (A) valve for adjusting rate of flow from primary settling basin to filter pump suction well; (B) pump suction; (C) recirculated settled filter effluent; (D) pump discharge to filter; (E) valve for adjusting pumping rate; (F) final settling basin effluent pipe discharging into flow control box; (G) adjustable effluent elbow (recirculation rate dependent on setting of this elbow); and (H) effluent collection pipe.

FIGURE 3.—Pilot plant, showing primary settling basin (foreground), trickling filters (background and right), and final settling basins (beneath filters).

of primary basin effluent and various rates of recirculation to the different filters. The effluent elbow, G, was adjustable so that the rate of recirculation could be maintained as desired.

A separate final sedimentation basin was provided for each filter by means of a 22.5-in. diameter, 55-gal. oil barrel located directly under each filter; a hopper-shaped bottom was formed and a sludge drawoff pipe was installed in each basin. Filter effluent was directed against the side of the barrel at about mid-depth, 180° from the location of the effluent weir. A section of a structural angle was installed for the effluent collection trough. Filters were dosed at rates of from 0.13 to 0.75 g.p.m., including recirculation, which resulted in detentions from about 5 hr. to slightly less than 1 hr. in the final settling basins.

Preliminary studies indicated that the best coagulant was alum, activated silica, and lime; however, due to the difficulties of adding a line suspension, potassium hydroxide was substituted in the pilot plant. The feeding of KOH was suspended shortly after operations were started because it was found to be unnecessary. However, some KOH was added, during a period when surface runoff decreased the alkalinity, with some benefit to the coagulation process. Figures 3 and 4 are views of the pilot plant.

Primary Treatment

Some of the primary effluent waste characteristics and the coagulant dosages are shown in Figures 5 and 6. The 5-hr. detention in the primary basin is considered to be largely responsible for the extreme variations in

FIGURE 4.—Pilot plant coagulation facilities.

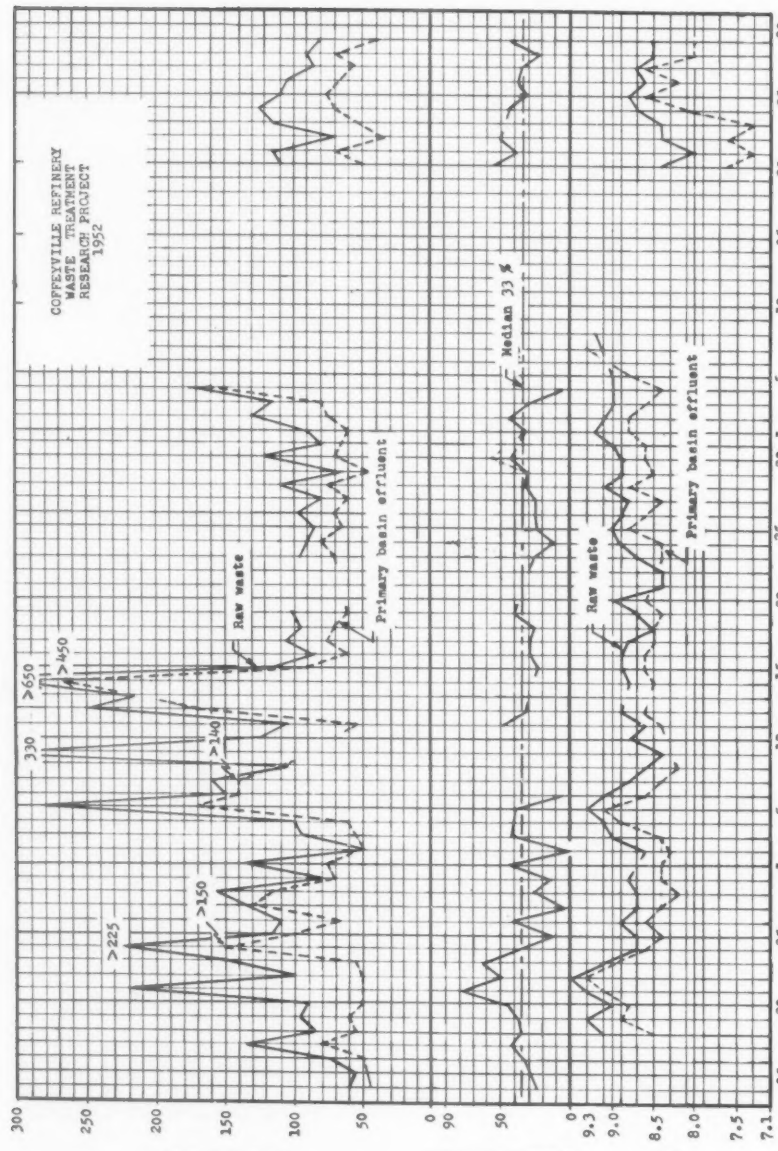


FIGURE 5.—B.O.D. and pH of raw refinery waste and primary effluent, and efficiency of primary treatment as measured by B.O.D. removal.

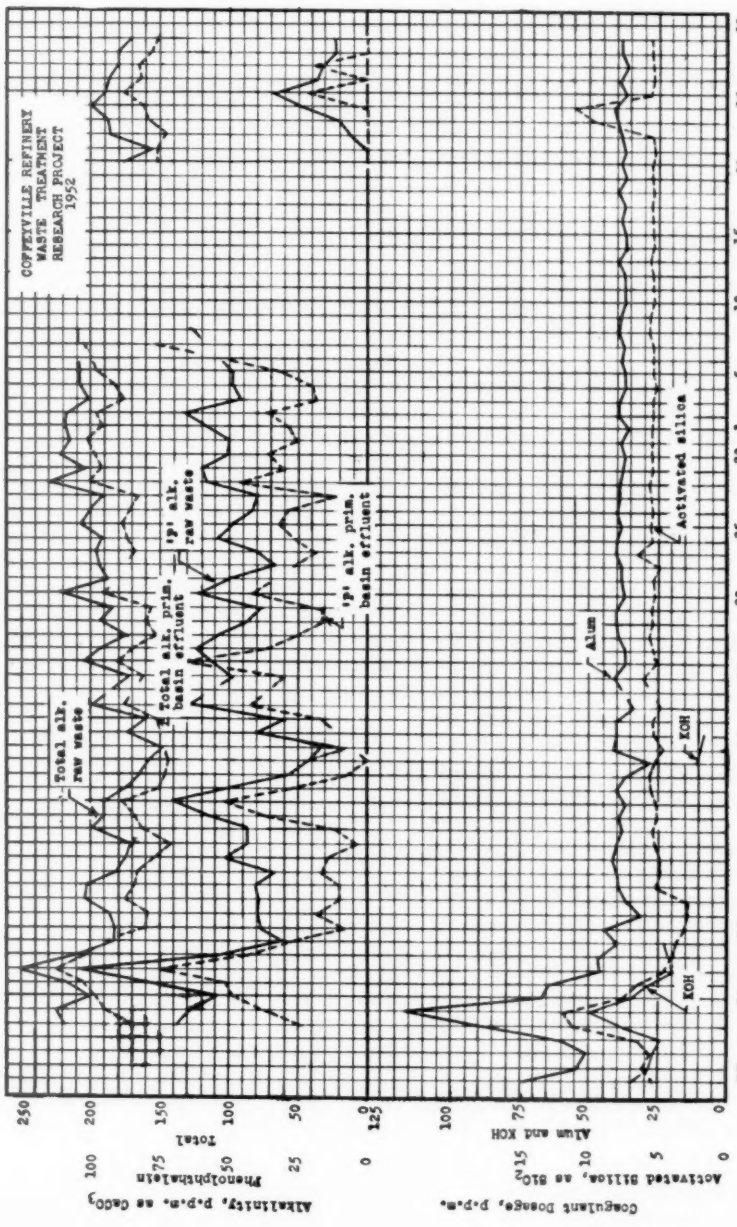


FIGURE 6.—Phenolphthalein and total alkalinity of raw refinery waste and primary effluent, and coagulant dosage for primary treatment in pilot plant.

B.O.D. removal. The median value of 33 per cent B.O.D. removal in primary treatment is considered to be representative of the treatment to be expected with reasonable coagulant dosages. The large variation in raw waste B.O.D. from day to day is in agreement with preliminary results obtained the previous year at this refinery (1) and stream studies in the vicinity of other refineries.

It was found that the turbidity was reduced to 100 p.p.m. or less in all except one primary effluent composite sample tested. The percentage of removal varied from 47 to more than 84 per cent.

Relatively constant alum dosages of 35 to 40 p.p.m. and activated silica dosages of 5 to 6 p.p.m. resulted in oil removals of from 9 to 86 per cent in the primary effluent samples analyzed; again, the variation in oil removal is largely due to the 5-hr. detention in primary treatment. The one primary effluent sample which contained more than 100 p.p.m. of oil was obtained on the day following the maximum surface runoff.

Although satisfactory clarification was obtained for more than a 2-month period from relatively constant alum and activated silica dosages, it should be pointed out that careful adjustment of the flocculation mechanism was necessary to produce the floc. The peripheral velocity of the flocculation paddles was reduced to about 1.3 ft. per sec. and there were indications that a slower velocity would have resulted in a better floc formation. However, it was not possible to obtain a slower speed with the pilot plant as constructed. The floc was rather fragile and would readily break up if agitated. The temperature of the raw waste was undoubtedly an aid to flocculation.

Trickling Filters and Final Sedimentation

The pilot plant was placed in operation on February 5 and although the primary treatment facilities were only operated a short time during each day, the filters were maintained in constant operation from that day on, with the exception of filter No. 6. A pump failure removed the latter unit from operation from April 4 through 20, but the growth was kept active by manual application of primary effluent several times each day. Beginning February 12, the plant was in full-time operation.

B.O.D. removals were apparent as early as February 14 and all the filters were effecting comparable B.O.D. removals by the end of February with recirculation ratios varying from 1.5 to 5.0 and water loadings from 8.8 to 29 m.g.a.d. During the latter part of March the seeding of all filters with Coffeyville sewage treatment plant effluent (except No. 4, which was never seeded) was discontinued, but the filters were continued in operation at the same rates of flow. By March 12 it was evident that all of the filters were in good condition and showing satisfactory B.O.D. removal. The flows to the filters were then adjusted according to Table IV.

TABLE IV.—Trickling Filter Flow Data

Filter	Filter Flow Rate (g.p.m.)			Filter Water Load (m.g.a.d.)	Recirc. Ratio
	Primary Effluent	Final Effluent	Total		
1	0.13	—	0.13	3.0	0
2	0.13	0.06	0.19	4.4	0.5
3	0.25	—	0.25	5.8	0
4	0.25	0.13	0.38	8.8	0.5
5	0.25	0.25	0.50	11.6	1.0
6	0.38	—	0.38	8.8	0
6	0.25[1]	0.50	0.75	17.4	2.0
7	0.38	0.37	0.75	17.4	1.0

[1] Raw waste April 22 to 29.

Table V presents information on waste applied to filters, as well as on the filter effluent. The phenol data, although based on a limited number of analyses, are comparable with the

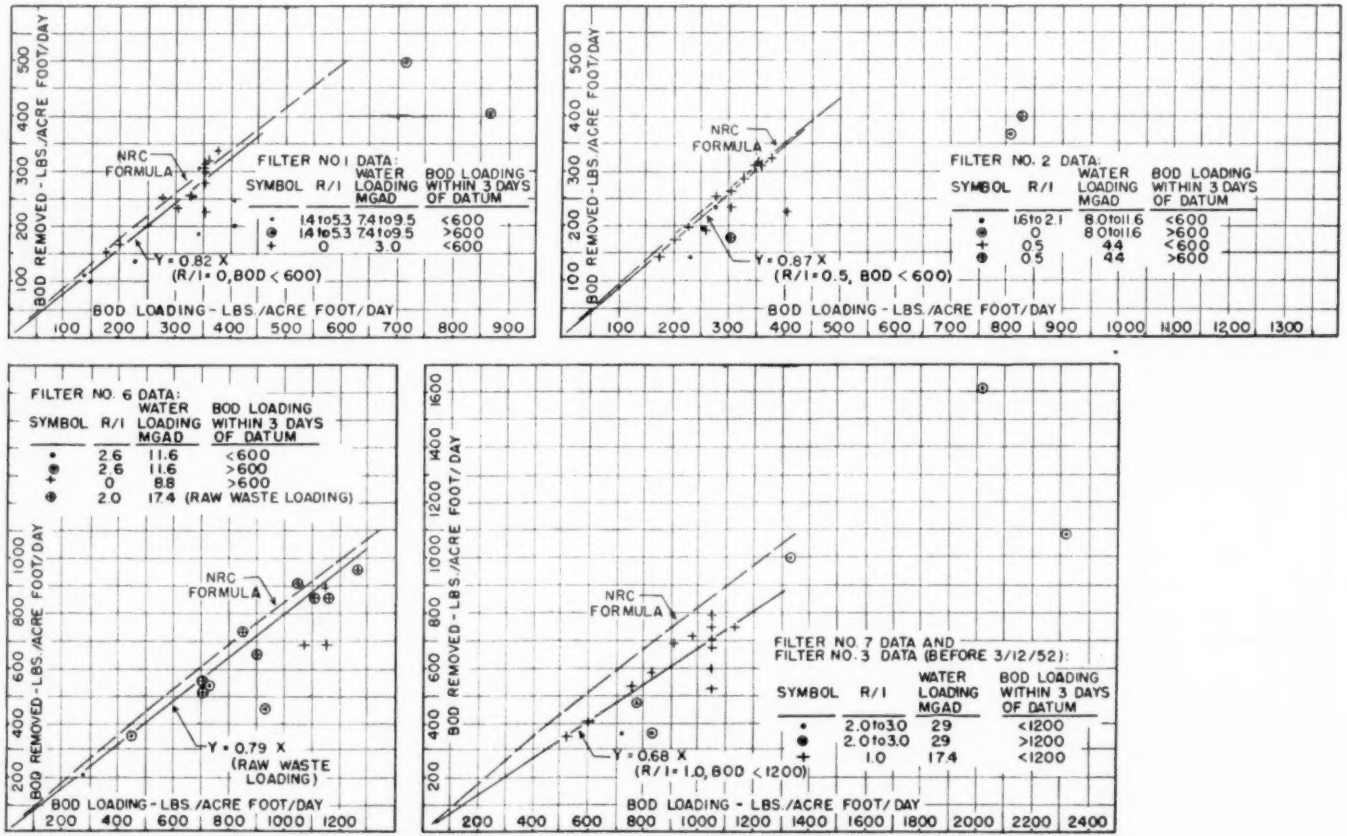


FIGURE 7.—Data and performance curves for filters 1, 2, 6, 7, and 3.

TABLE V.—Data [1] on Waste Applied to Filters and on Filter Effluents

Item	Median	Range
Air temperature (°F.):		
Daily minimum	34	14 – 58
Daily maximum	53	27 – 84
Coag. and settled waste:		
Temp. at 1-hr. int. (°F.)	73	46 – 92
B.O.D. (p.p.m.)	70	35 – >450
Phenols (p.p.b.)	4,000	500 – 4,500
Alkalinity (p.p.m.):		
Phenolphthalein	26	0 – 76
Total	170	142 – 224
pH	8.5	7.3 – 9.3
Turbidity (p.p.m.)	60	<25 – 240[2]
Oil (p.p.m.)	30	10 – 270[2]
Diss. oxygen (p.p.m.)	1.5	0 – 5.8
Filter effluents:		
Temp. at 1-hr. int. (°F.)	52[3]	32 – 80
pH	7.5[4]	7.2 – 8.4
Diss. oxygen (p.p.m.)	5.7[5]	0.0[6] – 10.2

[1] Based on 24-hr. composite samples unless otherwise noted.

[2] One sample > 100 p.p.m.

[3] Range of the medians for 7 filters, 48° to 57° F.

[4] Range of the medians for 7 filters, 7.5 to 7.7.

[5] Range of the medians for 7 filters, 5.3 to 7.1.

[6] One sample contained 0.0 p.p.m. D.O.

data obtained at the refinery over a period of several years.

Table VI is a summary of pH determinations on the primary effluent.

B.O.D. Removals

The performance curves for the various filters are shown in Figures 7 and 8. All of the data obtained for each filter is plotted, but the performance curves are based on the rates of application and recirculation ratios in Table IV, with the performance curve for filter 6 pertaining to the application of raw waste. In addition to the performance curves, the NRC (2) curve is shown.

TABLE VI.—Summary of pH Determinations Made at 2-Hr. Intervals on Primary Effluent

pH	No. Times Occurring	% of Total
>10.0	—	—
9.6–10.0	21	2.49
9.1– 9.5	28	3.32
8.6– 9.0	426	50.4
8.1– 8.5	328	38.81
7.6– 8.0	26	3.08
7.1– 7.5	8	0.95
<7.0	8	0.95
Totals	845	100

It is concluded from the performance curves for filters 1 and 2 that, at B.O.D. loadings up to 400 lb. per acre-ft. per day and recirculation ratios from 0 to 0.5, the filters performed in substantial accordance with the NRC formula. From the performance curves for filters 3, 4, and 5, it is concluded that, at B.O.D. loadings up to 800 lb. per acre-ft. per day and recirculation ratios of 0 to 1.0, the filters performed a little less efficiently than would be predicted by the NRC formula; the efficieney increased less than predicted by the formula as the recirculation ratio increased. From the curve for filter 7 it is concluded that at the heaviest loadings, up to 1,200 lb. per acre-ft. per day and a recirculation ratio of 1.0, the filter efficiency was less than would be predicted by the NRC formula for domestic sewage.

It is entirely possible that the method of final sedimentation was, at least in part, responsible for the deviations from the NRC curve, since the greater the recirculation ratio for each group of filters, the shorter the detention provided in final settling following each filter.

The effluent from filter 6, while the raw waste was being applied to it, was much more turbid and cloudy than was the effluent from any of the other filters; usually the effluents from the lighter loaded filters were less turbid and cloudy than was filter 7 effluent.

Filter Growths

From visible evidence, all of the filter growths had the same appearance until raw refinery waste was applied directly to filter 6. The sludge in all of the filter effluents, with the exception of filter 6 after raw waste was applied to it, settled readily to form a sludge of about the same characteristics as would be expected from a

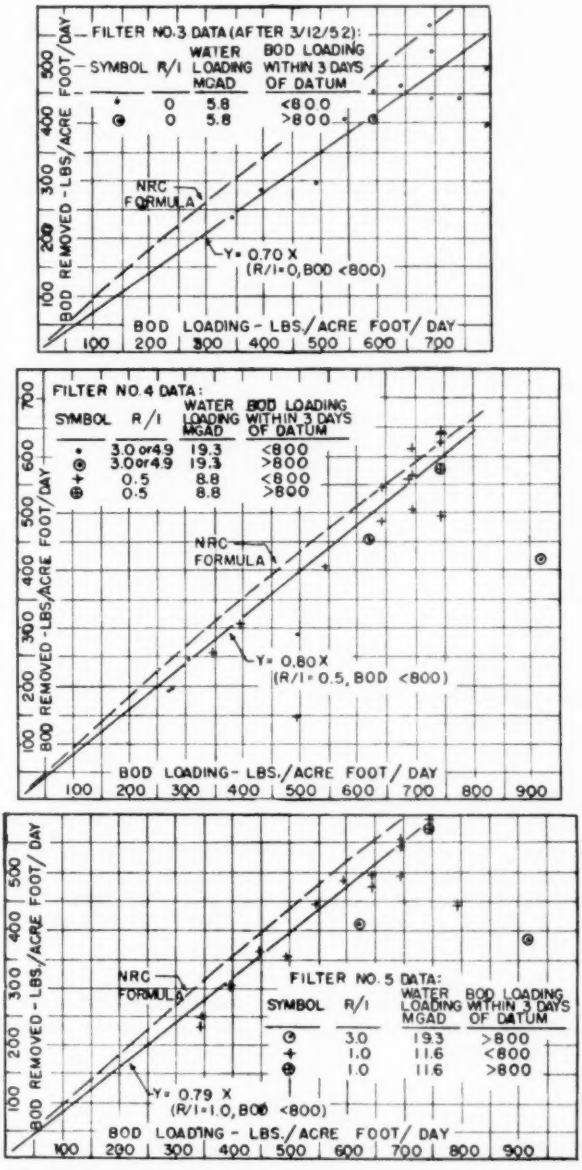


FIGURE 8.—Data and performance curves for filters 3, 4, and 5.

filter treating domestic sewage. There was every indication from the type of sludge produced that final settling basin design practices for sewage treatment plants should be applicable to final settling basins following trickling filters treating the primary treated waste from this refinery.

The study indicates that the direct application of this raw refinery waste to trickling filters is not practical. After operating filter 6 on raw waste for only 9 days the biological growth in the filter and the settled sludge from the filter effluent had an entirely different appearance than did the rest of the filter sludges. The sludge did not settle readily and it had a very high water and oil content after sedimentation did occur. The top 1 ft. of rock was removed from filters 1, 6, and 7 the day the study was completed. The biological growth from filter 6 contained a gross amount of oil. Also, a larger quantity of material was attached to the rock than was found in the other filters. It was concluded from this observation that the filter might have ponded under the loading conditions if it had continued in operation. In contrast, the biological growth from the other two filters had a slightly oily appearance and feeling but, in general, appeared to be comparable to that found in domestic sewage filters; samples of the sludge digested at room temperature. There was no evidence that ponding might occur in the filters which received coagulated and settled waste.

It is concluded that the biological growth in a filter adsorbs and/or absorbs the oil from the waste applied to it. Since oil is not readily utilized by bacteria, most of it was carried to the final settling basin with the sloughed biological growth. This oil, which was mostly non-separable or emulsified, was enmeshed in the organic matter and tended to keep the sludge in suspension. It also appears that the concentration of oil in the waste applied to a filter can cause final sedimentation difficulties, even though it is lower than the concentration which would cause an inhibiting effect on the filter organisms and reduce their capacity to oxidize organic matter. Probably the amount of oil which would inhibit the filter bacteria depends upon the total amount of oil applied per unit of filter volume, rather than on concentration.

There was every indication that not only would it be necessary to provide 50 per cent more filter volume and two or three times as much final settling capacity if the raw refinery waste were treated on a trickling filter, but it also is likely that a sludge dewatering problem would be encountered.

Special Studies

Nitrogen Data

Table VII contains a summary of nitrogen data for the primary settled effluent and settled filter effluents. From these data it is concluded that the refinery waste did not contain large amounts of organic, nitrite, or nitrate nitrogen, but that it did contain a relatively large concentration of ammonia nitrogen.

TABLE VII.—Summary of Nitrogen Data from April 7 to 29, 1952

Source	Nitrogen (p.p.m. as N)							
	Organic		Ammonia		Nitrite		Nitrate	
	Median	Range	Median	Range	Median	Range	Median	Range
Primary basin	1.5	0.10–2.30	11.0	6.0–19.0	0.04	0.03–0.07	0.16	0.10–0.33
Filter No. 1	0.45	0.10–1.92	9.5	5.0–12.8	0.22	tr. –0.33	0.97	0.27–1.60
Filter No. 2	0.20	0.0 –1.80	8.0	3.0–12.8	0.33	0.18–0.60	1.20	0.66–2.10
Filter No. 3	0.32	0.0 –1.90	8.0	5.0–12.8	0.08	0.01–0.20	0.26	0.20–0.64
Filter No. 4	1.6	0.72–2.30	8.0	4.0–12.0	0.08	0.02–0.25	0.34	0.19–0.52
Filter No. 5	0.20	0.08–1.50	9.0	4.0–12.8	0.03	0.02–0.10	0.31	0.24–0.52
Filter No. 7	1.60	0.48–2.00	10.9	5.0–11.0	0.03	tr. –0.07	0.22	0.16–0.28

TABLE VIII.—B.O.D.—Nitrogen—Phosphate Relationship in Primary Effluent

Date	B.O.D.[1] (p.p.m.)	Total Nitrogen, as N (p.p.m.)	Soluble Phosphates, as P (p.p.m.)	Ratio, B.O.D.[1]:N:P
Apr. 20, 1952	50	12.9	3.8	13.1:3.4:1
Apr. 21, 1952	70	9.6	3.8	18.4:2.5:1
Apr. 27, 1952	55	12.8	3.3	16.6:3.9:1

[1] Seeded "Standard Methods" phosphate buffer dilution water.

Some of the organic and ammonia nitrogen was converted to nitrites and nitrates, although a considerable amount of the ammonia was not oxidized by the filters; the lighter B.O.D. loaded filters provided the greatest degree of nitrification. That the settled filter effluents at times contained considerable concentrations of organic nitrogen may be attributed to the type of final sedimentation, which may have permitted some carryover of suspended solids when relatively large quantities of growth were sloughing from the filter media. Also, some of the algae growing on the effluent collection troughs may have been present in occasional samples.

Since the receiving stream is relatively clear, is a source of public water supplies, and low stream flows at times afforded little dilution, it is concluded that further treatment, in addition to trickling filters, will be needed to oxidize the ammonia.

B.O.D.-Nitrogen-Phosphate Relationship

Table VIII presents limited data indicating that the B.O.D.-nitrogen-phosphate relationship was well within the 60:3:1 ratio generally needed for efficient bacterial activity.

Phenols

Some phenol studies (Table V) were made to substantiate, if possible, the conclusion made from river studies (3)(4) that most of the phenols and related compounds are oxidized before the organic matter in refinery waste is oxidized sufficiently to prevent stream pollution. Although all of the filters removed a high percentage of the phenolic compounds, the limited data indicate that as the loading increased there was a considerable increase in phenol concentration in the filter effluent.

Filter loadings for all of the filters, in addition to B.O.D., ranged from 2.5 to 67.7 lb. of phenols per acre-foot per day. The efficiency in phenol removal ranged from 93.3 to 99.6 per cent, with the phenol concentration in the filter effluents ranging from 25 to 300 p.p.b.

Comparison of B.O.D. Dilution Waters

To gain further information about the oxygen demand of the raw refinery waste, three different dilution waters

TABLE IX.—Comparison of Refinery Waste 5-Day, 20° C., B.O.D.'s, Using Three Dilution Waters

Date (1952)	B.O.D. (p.p.m.)		
	Bicarbonate[1] Dilution Water	Phosphate[1] Dilution Water	Verdigris River Dilution Water
Apr. 20	100	110	115
Apr. 21	105	115	120
Apr. 22	70	70	90
Apr. 23	105	115	140
Apr. 24	100	125	155
Apr. 25	95	110	135
Apr. 26	90	105	110
Apr. 27	—	85	—
Apr. 28	—	90	100
Apr. 29	—	70	95
Minimum	70	70	90
Median	100	108	115
Maximum	105	125	155

[1] Seeded with filter No. 1 effluent.

—bicarbonate, phosphate, and Verdigris River water—were used in making 5-day, 20° C., B.O.D. analyses. The river dilution water consisted of 18 l. of water obtained above the refinery and 0.5 l. obtained about one river mile downstream from the refinery outfall sewer. The river water was aerated for two weeks; it was then settled, with the clear water being siphoned to another carboy and stored in the dark for one week before the work was begun; the water was stored in the dark an additional 10 days during the study without further aeration. The initial D.O. of the river dilution water used in the analyses ranged from 6.8 to 7.4 p.p.m.; after five days incubation it ranged from 6.3 to 7.0 p.p.m. Series studies indicated that significant ni-

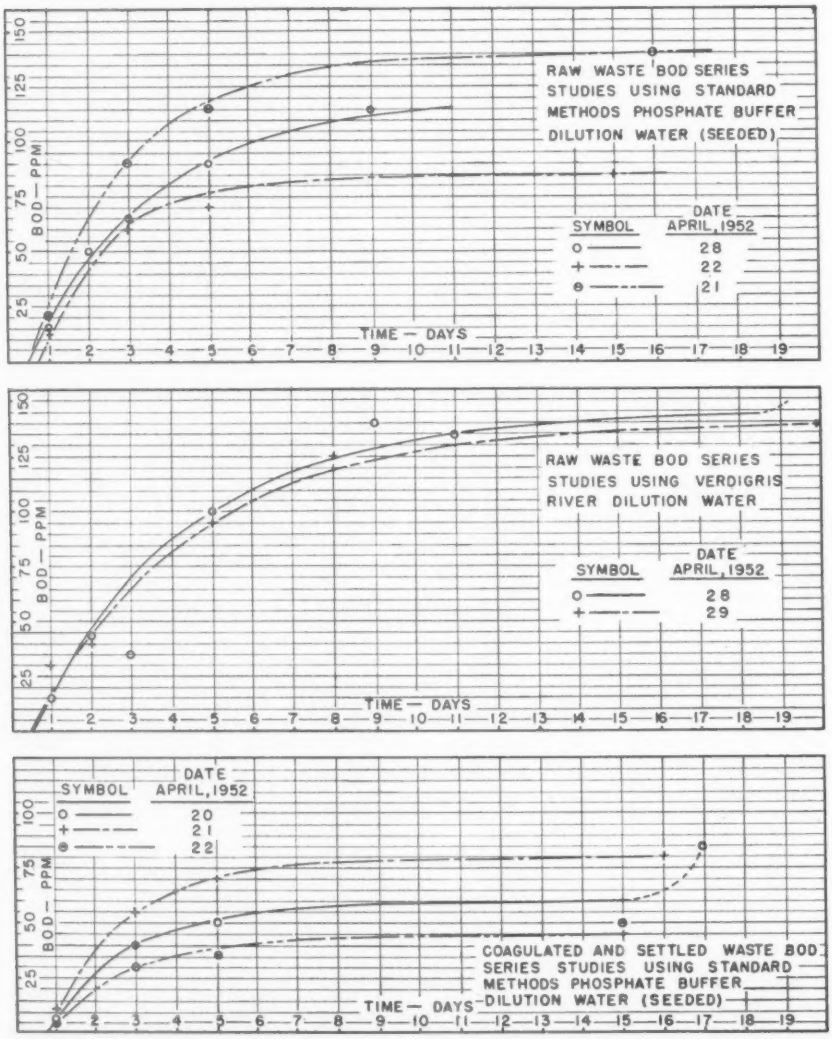


FIGURE 9.—B.O.D. series studies using various dilution waters.

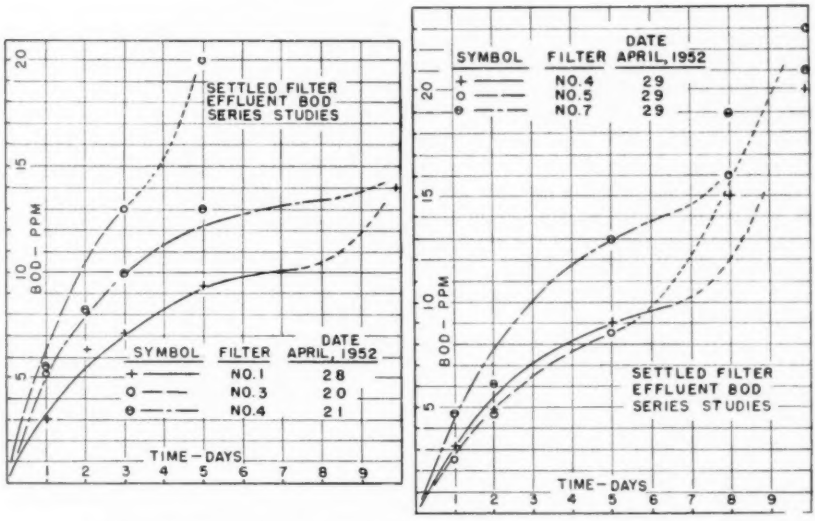


FIGURE 10.—Results of settled filter effluent B.O.D. series studies.

trification did not occur in river dilution water during 10 days of incubation. Results obtained with the different dilution waters are presented in Table IX.

The B.O.D. obtained using bicarbonate dilution water ranged from 80 to 100 per cent of the B.O.D. obtained using the phosphate buffer dilution water, with the median value being 91 per cent. The B.O.D. using Verdigris River dilution water ranged from 104 to 143 per cent of that obtained using phosphate buffer dilution water, with the median value being 122 per cent. These percentages are based on the individual results for each day and not on the minimum, median, and maximum summation for all the tests. These data indicate that the raw waste oxygen demand exerted on the stream was actually greater than was indicated by the usual laboratory dilution water. Therefore, it is possible that the B.O.D. exerted on the filters was actually greater than is indicated in the performance curves. Nevertheless, since river water was not used in analyzing the filter effluents, it is not possible to conclude that the filters were more efficient than is indicated.

Series B.O.D. Data

A number of series B.O.D. analyses were made on raw waste, coagulated and settled waste, and various settled filter effluents in order to obtain further information about the oxygen demand characteristics of the refinery waste and because very few data of this type have been previously obtained and reported. Some of the results obtained from these series studies are presented in Figures 9, 10, and 11.

There was a lag of about 0.5 to 0.75 days before the B.O.D. in the raw waste and primary settling basin effluent was exerted; after the lag period the oxygen demand was exerted in a manner similar to that which occurs in sewage and stream samples. A lag did not occur before the settled filter effluents began exerting their oxygen demands. Table X contains k_1 and L values for the curves plotted in Figures 9, 10, and 11. These k_1 values are within the usual range for domestic sewage, but most of them are higher

than the average. The k_1 values also compare favorably with values obtained from the Walnut and Little Arkansas Rivers (3) (4), where little or no dilution flow was available for raw refinery waste. The high second-stage B.O.D. found in these two river basin studies also supports the data obtained in this study, and the conclusion that additional treatment beyond trickling filters is necessary for relatively small clear streams and where water supplies are involved.

A high raw waste second-stage B.O.D. was indicated, but the data are insufficient to permit plotting the curves. Sufficient information was obtained, however, to permit plotting the second-stage B.O.D. for some of the settled filter effluents (Figure 11). The extremely high second-stage B.O.D. values are obvious, and these data confirm Izyurova's (5) findings that prolonged periods are necessary to oxidize oil refinery products in water.

Oxidation Pond Studies

During each of the last 10 days of the study (April 20–29), approximately 1 l. of the settled effluent from filters 1 and 7 was added to separate

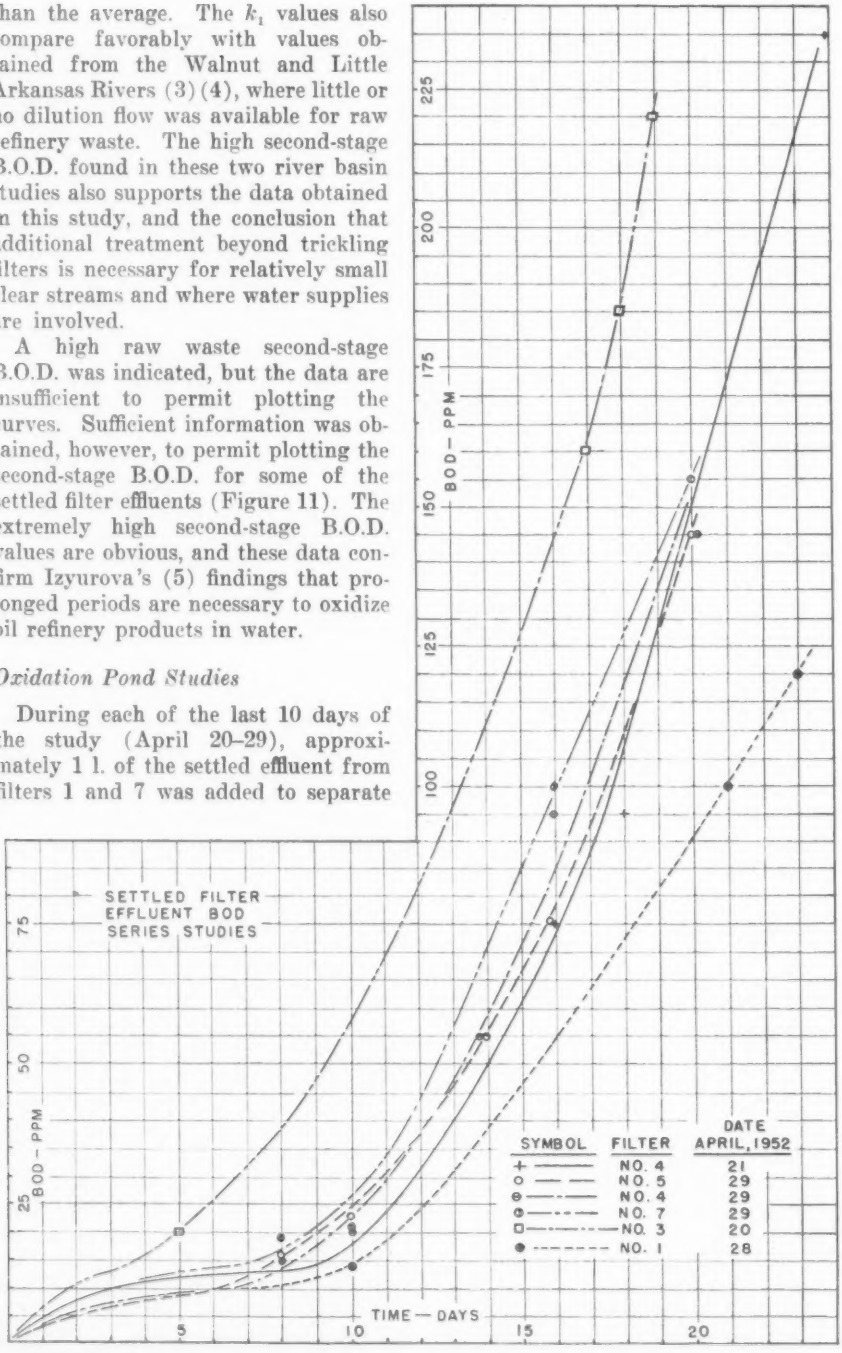


FIGURE 11.—Results of settled filter effluent B.O.D. series (second-stage) studies.

TABLE X.—First-Stage B.O.D. k_1 and L Values

Date (1952)	Raw Waste		Coag. and Sett. Waste		Sett. Filter Effl.	
	k_1*	L† (p.p.m.)	k_1*	L† (p.p.m.)	k_1*	L† (p.p.m.)
Apr. 20	—	—	0.21	60	0.21	17
Apr. 21	0.18	140	0.22	80	0.18	14
Apr. 22	0.24	90	0.21	45	—	—
Apr. 28	0.14	120	—	—	0.15	11
Apr. 28	0.11‡	145‡	—	—	—	—
Apr. 29	0.11‡	140‡	—	—	0.15	11
Apr. 29	—	—	—	—	0.13	11
Apr. 29	—	—	—	—	0.15	16

* First-stage 20°C., B.O.D. rate constant (per day).
† Ultimate first-stage 20°C. B.O.D.
‡ River water used for dilution.

TABLE XI.—Nitrogen Data for Simulated Oxidation Pond Treatment with Settled Filter Effluent

Date (1952)	Nitrogen (p.p.m. as N)							
	Filter No. 1				Filter No. 7			
	Tot. Org.	NH_3	NO_2	NO_3	Tot. Org.	NH_3	NO_2	NO_3
May 16	5.0	2.4	0.75	0.99	6.0	2.6	0.28	0.15
June 4	1.8	0.28	0.38	0.23	0.16	1.7	0.01	0.07
July 2	1.6	1.2	0.01	0.14	3.0	0.08	0.01	0.04

carboys and exposed to the sunlight. This was done to determine the treatment which might be provided to a filter effluent in an oxidation pond. The oxidation pond nitrogen data are presented in Table XI.

Much of the nitrogen was converted into living organisms during the storage period. The results of microscopic examinations of the oxidation ponds on April 30, May 16, June 4, and July 2, 1952 (10, 26, 45, and 73 days, respectively, after the ponds were started) are as follows:

April 30, 1952—Filter 1 effluent: There were many flagellates, predominantly *Chlamydomonas* and a very few specimens of *Strauroneis* and *Navicula.*

Filter 7 effluent: There was an extremely prolific growth of small flagellates, predominantly *Chlamydomonas* plus a few specimens of *Strauroneis* or *Navicula.* There was a greater concentration of all organisms than was obtained in filter 1 effluent.

May 16, 1952—Filter 1 effluent: *Chlamydomonas,* of which there were probably two species, constituted the predominant organisms. Numerous specimens of *Chlorella,* both free-floating and in masses, were also present. A few filaments of the blue-green algae, *Oscillatoria,* and a few unicellular green algae, *Selenastrum* and *Scenedesmus,* were observed. An amoeba, a few *Paramecium,* some other small ciliates, and numerous specimens of a larger ciliate constituted the protozoan organisms.

Filter 7 effluent: There were both free-floating and massed specimens of *Chlamydomonas* and *Chlorella* in this sample. Filaments of *Oscillatoria* were interwoven in the above masses and were more numerous than in the filter 1 sample. A few specimens of

the filamentous green algae, *Microspora*, and the unicellular green algae, *Scenedesmus*, were observed. Of the protozoa group the amoebae were more numerous and the ciliates less numerous than in filter 1 effluent.

June 4, 1952—Filter 1 effluent: Mats of two species, one very small, of the filamentous blue-green algae, *Oscillatoria*, were observed. Also there were numerous specimens of two species of *Chlamydomonas*, both free-floating and entangled in masses of floating algae growths, giving the mats of algae a green appearance. Protozoa were not observed.

Filter 7 effluent: Mats of two species of the filamentous blue-green algae, *Oscillatoria*, were observed. *Chlamydomonas* was as abundant as in filter 1 effluent and was both free-floating and entangled in floating mats of algae. Only one unicellular green algae, a *Scenedesmus*, was observed; no protozoa were found.

July 2, 1952—Filter 1 effluent: There were brownish-green floating masses of debris, *Chlamydomonas*, filaments of the blue-green *Oscillatoria*, and dead algal cells. There were few encysted green algae, with no vegetative forms being observed. *Chlamydomonas* cells were not found, nor were any protozoa observed.

Filter 7 effluent: There were grayish-green floating masses of debris, very fine blue-green algae and a few filaments of a larger form, probably *Oscillatoria*, and dead algal cells. There were a few encysted green algae, with no vegetative forms being observed. *Chlamydomonas* cells were not found, nor were any protozoa observed.

Dissolved oxygen determinations were made on oxidation pond samples about 8:00 AM each day during the first 10 days. The D.O. was always at or above saturation, and one sample contained nearly 22 p.p.m.; supersaturation during the first weeks was obvious because many oxygen bubbles could be seen rising to the surface in each carboy. The same type and kind of biological activity took place in the oxidation ponds as has been observed in streams (3)(4) after they began to recover. Data obtained in the Walnut River study (3) indicate the effects of a second-stage B.O.D. in the stream, beginning an estimated 15 to 20 days downstream from refineries. Prolific algae growths, consisting mostly of *Euglena* and similar organisms which can utilize ammonia, are found throughout the year in the Little Arkansas and Walnut Rivers after the streams have recovered from the gross effects of refinery pollution.

In view of reports from California (6) it is entirely possible and practical to consider oxidation ponds as a means of converting organic matter into biological life and then remove the biological life from the effluent before discharging it to a stream. Possibly the British microscreen (7)(8) could be utilized to effect removal of biological life from an oxidation pond effluent before it is discharged to the river.

Biological Information about the Filters

A microscopic examination of the film on the rock media in filters 1 and 7 on April 28–30 indicated that similar biological forms were present in both. The rock film consisted of an amorphous, gelatinous, zooglea mass interlaced with hyphae of a spaerotilis-like fungus and contained a moderate number of ciliate protozoans, flagellate algae, and nematode worms. The composition of the filter growths was similar to that usually described for filters treating sewage.

It is of interest to note than an examination of the biological growths attached to the bottom of the effluent collection troughs in the final settling basins showed that *Chlamydomonas* and *Vorticella* were common to all; *Lionatus* and nematodes were common

to all, except that none was found in filter 6 samples. *Paramecium* was common to all except filters 1 and 2; *Oscillatoria* was only found in filter 1 samples.

Oxygen Consumed Information

A number of oxygen consumed (O.C.) analyses were made, but the data are not reported since the O.C.: B.O.D. ratio varied and there was no correlation between the tests. The possibility of using the oxygen consumed test for plant control should not be overlooked. A number of oxygen consumed tests each day on samples composited over a few hours would provide knowledge of unusual waste discharges and permit tracing them to their source. It is generally difficult to trace spills after five days—the time necessary for the usual B.O.D. analysis—have elapsed.

Summary

1. A constant portion of raw refinery waste for a three-month period was treated successfully by means of coagulation with alum and activated silica, primary sedimentation, trickling filters, and final sedimentation.

2. Although there was not usually a great variation in the rates of raw waste flow during any day, there was a day-to-day variation. The ratio of maximum to minimum rate of flow, not including surface runoff, was about 3.5 : 1.

3. A nearly constant alum and activated silica dosage for more than two consecutive months provided adequate coagulation to condition the waste for biological treatment.

4. The high temperature of the raw waste, even in cold weather, was an aid to the coagulation process.

5. The filters performed satisfactorily through a much wider range of varying temperatures than would be expected in a large treatment plant.

6. The filters performed in close agreement with the NRC (2) formula for filters treating settled sewage. The efficiency decreased from the efficiency predicted by the formula as the loadings and recirculation ratios increased.

7. Phenols were well oxidized, particularly in the lightest loaded filters.

8. The biological activity in the filters made an adjustment from an applied waste pH of 8.6 to 9.0, occurring 50 per cent of the time, to a pH range of 7.2 to 8.0. An occasional slug of raw waste having a high pH (up to 11.0 on two occasions) did not have an adverse effect on the filters.

9. Other than a lag period of from 0.5 to 0.75 days, the raw waste B.O.D. was exerted in a manner similar to that of domestic sewage. The 20° C. k_1 values ranged from 0.11 to 0.24 in the waste applied to the filters and from 0.13 to 0.21 in the filter effluents.

10. Raw refinery waste was applied to one filter for a period of 9 days. The B.O.D. removal was comparable to the other filters, but an oily, poor-settling final sludge and a turbid settled effluent resulted. The filter growth developed into an oily mass and ponding appeared imminent after only 9 days with a B.O.D. loading under 1,200 lb. per acre-ft. per day, a recirculation ratio of 2.0, and a water loading of 17.4 m.g.a.d.

Conclusions

1. A separate drainage system, not open ditches, is indicated.

2. All waste and surface runoff water from processing and storage areas should receive treatment.

3. Flocculation and sedimentation in separate basins is indicated by the fragile floc and observations made while adjusting the speed at which the flocculation paddles rotated.

4. Pretreatment is indicated for the strongest individual ammonia waste(s) to remove approximately 70 per cent of the total ammonia.

5. Oxidation pond treatment of settled filter effluent for approximately 60 days is indicated before the waste is discharged. The pond will allow

the use of the higher filter loadings and will absorb shock loads.

6. Although the Cooperative Refinery at Coffeyville discharges only 105 gal. of waste per barrel of crude oil, compared to the 770-gal. average in the Ohio River report (9), it is probable that the quantity could be further reduced through re-use of adequately treated waste, and possibly other conservation measures. This is an important consideration, since at this and other midwest refineries prolonged minimum stream flows are not always adequate for the process water supply, and storage reservoirs are desirable.

Acknowledgments

The author gratefully acknowledges the assistance rendered in the conduct of this study by R. D. McCrum and Glen Kinnick of the Cooperative Refinery Association; Charles T. Black, graduate student, University of Kansas; Herman Janzen, Howard Stoltenberg, Burton B. Hodgden, Cassandra Ritter, and Roger Lee of the Kansas State Board of Health staff; William Ketterman, refinery process engineer, who supervised operation and maintenance of the pilot plant; and operators England, Gilpin, Odle, Robertson, and Soles.

References

1. Peterson, E., "Testing of Plant Waste Water, 1951." Report to Cooperative Refinery Assn.
2. National Research Council, "Sewage Treatment at Military Installations." *Sewage Works Jour.*, **18**, 5, 789 (Sept., 1946).
3. "Water Pollution Report, Walnut River Basin." Div. of Sanitation, Kansas State Board of Health (1952).
4. Unpublished data from Little Arkansas River Pollution Study, Div. of Sanitation, Kansas State Board of Health (1952, 1953).
5. Izyurova, A. I., "Rate of Oxidation of Petroleum Products in Water Without Addition of Nitrogen." *Gigiena i Sanit.*, No. 7, 12 (1952); *Chem. Abs.*, **46**, 10507g (1952).
6. Oswald, Gotaas, Ludwig, and Lynch, "Algae Symbiosis in Oxidation Ponds. I. Growth Characteristics of *Euglena gracilis* Cultured in Sewage." THIS JOURNAL, **23**, 11, 1337 (Nov., 1951); "II. Growth Characteristics of Chlorella pyrenoidosa Cultured in Sewage." THIS JOURNAL, **25**, 1, 26 (Jan., 1953); "III. Photosynthetic Oxygenation." THIS JOURNAL, **25**, 6, 692 (June, 1953).
7. Boucher, P. L., "Micro-Straining." *Jour. Inst. Water Eng.* (Brit.), **5**, 561 (1951).
8. "Water Pollution Research, 1951." Report of the Water Pollution Research Board, England (1952); abs. THIS JOURNAL, **25**, 4, 507 (Apr., 1953).
9. "Report on Survey of the Ohio River, Supplement D, Industrial Waste Guide." U. S. Pub. Health Serv., Washington, D. C. (1943).

SMALL-SCALE LABORATORY UNITS FOR CONTINUOUSLY-FED BIOLOGICAL TREATMENT EXPERIMENTS

I. Aeration Units for Activated Sludge

By Richard Hatfield and E. R. Strong

Chemist and Research Engineer, respectively, Waste Disposal Section, Department of Chemistry and Chemical Engineering, Southwest Research Institute, San Antonio, Tex.

In 1948, when the author's laboratory first began working on industrial waste disposal problems, all laboratory-scale activated sludge experimentation was performed using the conventional batch-fed, fill-and-draw units (Figure 1). This type of unit was chosen because it was the one that had been most widely reported in the literature by investigators in laboratory-scale studies on the activated sludge process.

The batch-fed unit is generally considered to be well-suited for acclimating a sludge to a particular waste and for obtaining oxidation rate data.

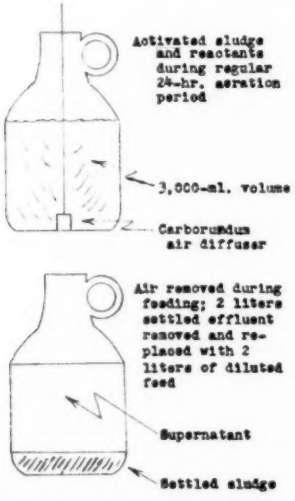

Activated sludge and reactants during regular 24-hr. aeration period
3,000-ml. volume
Carborundum air diffuser
Air removed during feeding; 2 liters settled effluent removed and replaced with 2 liters of diluted feed
Supernatant
Settled sludge

FIGURE 1.—Batchwise fill and draw activated sludge units using 1-gal. jugs as aerators.

However, two significant observations in the author's early experience led to the decision to change from batch-fed to some type of continuously-fed activated sludge units. These observations were as follows:

1. While working with a toxic organic waste in 1951 (1), it was found that a batch-fed unit could tolerate higher daily B.O.D. loadings when fed smaller amounts several times daily than when fed a large amount only once daily. Reducing the amount of feed at each feeding reduced the shock load of the toxic waste to the floc microorganisms such that more waste could be fed per day; however, increasing the frequency of feeding made this type of study very tedious and time consuming.

2. The continuously-fed units would more nearly simulate actual plant practice than would the fill-and-draw units. Also, the continuously-fed units are well adapted for studying recirculation ratios, sludge concentrations, and retention times.

Description of Aeration Units

A laboratory-scale unit, to be used for experiments in the treatment of industrial wastes or domestic sewage, was developed which permitted conditions for continuous feeding of raw waste, tap-water diluted waste, or an admixture of waste and treated effluent. The unit consists of a 2,000-ml.

rectangular aeration tank fabricated from galvanized iron or plastic sheeting. The aerator is an 8½-in. length of ¼-in. diameter Saran tubing perforated with 1/32-in. diameter holes at 3/16-in. intervals for air diffusion and extends lengthwise along one side of the bottom of the tank. A 200-ml. settling basin is built in at the end of the tank in such a way that settled sludge is automatically returned to the aeration chamber. The feeding tank consists of 2- to 8-l. aspirator bottle, the Mariot principle of constant-head pressure being utilized to assure a constant rate of feeding. When it is desired to feed larger volumes than this, the aspirator bottle is replaced by a Sigmamotor pump, as suggested by Coe (2), who reported results obtained with a similar type of continuously-fed laboratory unit for treating refinery wastes. One Sigmamotor pump has been utilized to simultaneously feed 6 aeration units. The laboratory bench-scale unit is shown in Figures 2, 3, and 4.

In operating a series of these units, it has been the practice at this laboratory to feed the units at the beginning

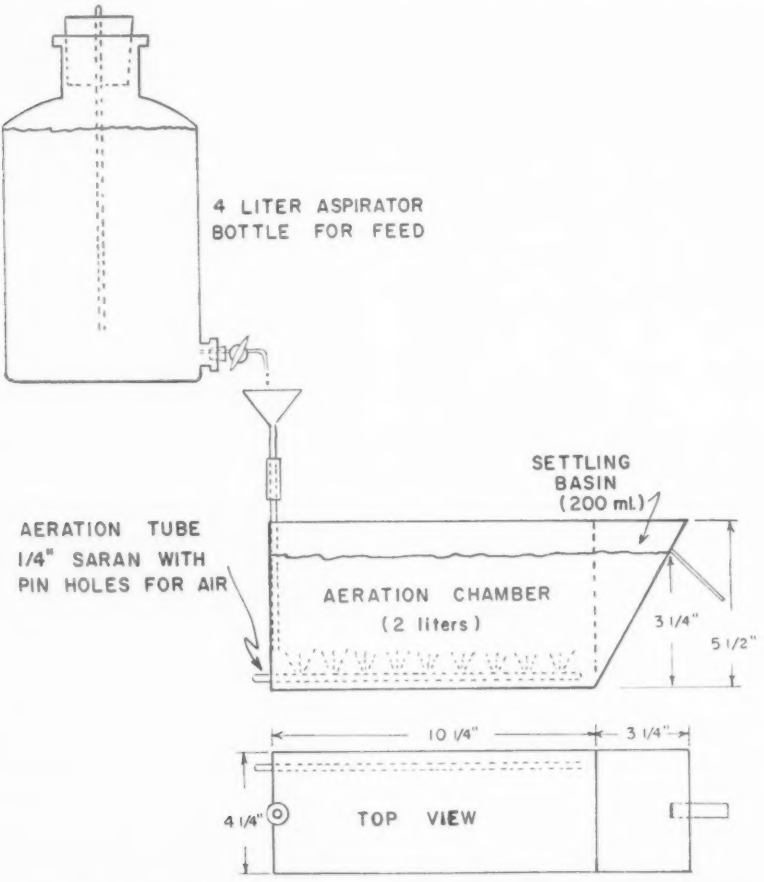


FIGURE 2.—Flow diagram of continuously-fed aeration unit used in activated sludge experiments.

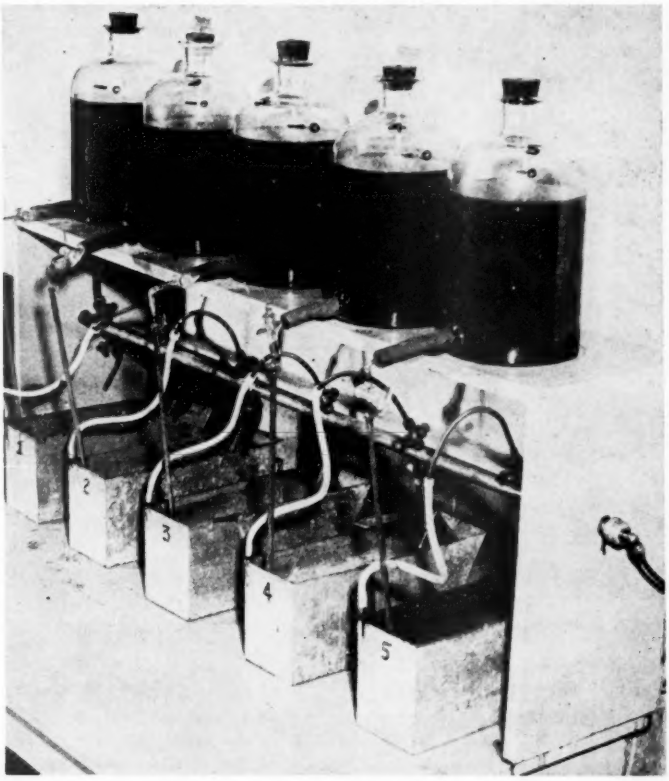


FIGURE 3.—Continuously-fed laboratory aeration units using constant-gravity feeding.

of each day and the resulting effluent is collected in a container large enough to hold one day's flow. If treated effluent is being recycled it is mixed with the raw feed in the aspirator bottle at the beginning of each day. In utilizing these units, the size of the aeration chamber has been varied from 250 to 2,000 ml. and the aspirator bottle feed tank from 2 to 8 l.

During three years, these units have been used in waste treatment studies on petrochemical, food processing, and paper mill wastes, as well as domestic sewage, and it is believed that they would be applicable to many other types of organic wastes. For applied B.O.D. loadings up to about 164 lb. per day per 1,000 cu. ft. of aeration volume in the case of a petrochemical waste, 1,000- and 2,000-ml. laboratory aeration units removed 99.2 to 99.5 per cent of the B.O.D. and a 375-gal. pilot plant removed 98.4 to 98.7 per cent of the B.O.D. (1). These values are well beyond conventional design data, yet the correlation between laboratory unit and pilot plant is excellent, even at 700- to 1,400-fold scale-up factors.

Summary and Conclusions

1. Three years of experience in the operation of the bench-scale continuously-fed activated sludge units described herein have demonstrated that many experiments can be carried on simultaneously in low-cost equipment

FIGURE 4.—Continuously-fed laboratory aeration units using pump feeding.

which requires very little attention other than one daily feeding.

2. B.O.D. removal efficiencies obtained with 1,000- and 2,000-ml. aeration units have been duplicated at similar loadings with a 375-gal. pilot plant.

3. The continuously-fed unit appears to more nearly simulate actual plant practice than does the batch-fed unit.

4. A continuously-fed unit can be used to advantage in studying a toxic waste, because this type of unit tends to lessen the effect of shock loads that are inherent in the operation of the batch-fed unit.

References

1. Strong, E. R., and Hatfield, R., "Treatment of Petrochemical Wastes by Superactivated Sludge Process." *Ind. Eng. Chem.*, **46**, 308 (1954).

2. Coe, R. H., "Bench-Scale Biological Oxidation of Refinery Wastes with Activated Sludge." THIS JOURNAL, **24**, 6, 731 (June, 1952).

Stream Pollution

INDUSTRIAL POLLUTION OF INTERNATIONAL BOUNDARY WATERS ALONG THE NIAGARA FRONTIER *

By Hayse H. Black and Earl Devendorf

Chief, Industrial Wastes Section, Robert A. Taft Sanitary Engineering Center, USPHS, Cincinnati, Ohio; and Director, Bureau of Environmental Sanitation, New York State Department of Health, Albany, N. Y.

Since the advent of hydroelectric power from Niagara River in 1895, industry has played an ever-increasing role in the development of the Niagara Frontier. Today Buffalo, the Tonawandas, and Niagara Falls, N. Y., constitute one of the highly industrialized areas of the United States. This discussion is confined to those industries located in the state of New York with particular reference to the International Boundary Waters during the period 1949–54. The east end of Lake Erie is included because of tributaries and Buffalo Outer Harbor, all of which have bearing on Niagara River pollution. Likewise, the effect of lower Niagara River pollution is traced into Lake Ontario (Figure 1).

Boundary Waters Control

Use of these International Boundary Waters is controlled by an International Joint Commission, consisting of six members, established in 1909 by a treaty between Great Britain and the United States. Article IV of this treaty stipulates that boundary waters and waters flowing across the boundary shall not be polluted on either side to the injury of health or property on the other side. At the request of the two governments, the International Joint Commission conducted a comprehensive survey of these boundary waters and principal pollution sources in 1948 and 1949. This work in the United States was performed by the U. S. Public Health Service under the general direction of a Board of Technical Advisors composed of eight engineers, four from the United States and four from Canada. The report on these studies (1) was accepted by both governments.

An outgrowth of the 1948–1949 studies was the adoption by the International Joint Commission of "Objectives for Boundary Waters Quality Control." Early in 1952, the Commission appointed an Advisory Board on Control of Pollution of Boundary Waters. This Advisory Board like the one it succeeded, is made up of eight engineers representing the two governments, the State of New York, and the Province of Ontario. One function of the Advisory Board is to critically examine industrial waste problems and pollution abatement programs directed toward compliance with the objectives and to evaluate and interpret progress for the International Joint Commission. The Advisory Board reports semi-annually to the Commission.

* Presented at 26th Annual Meeting, New York Sewage and Industrial Wastes Assn.; New York, N. Y.; Jan. 21–22, 1954.

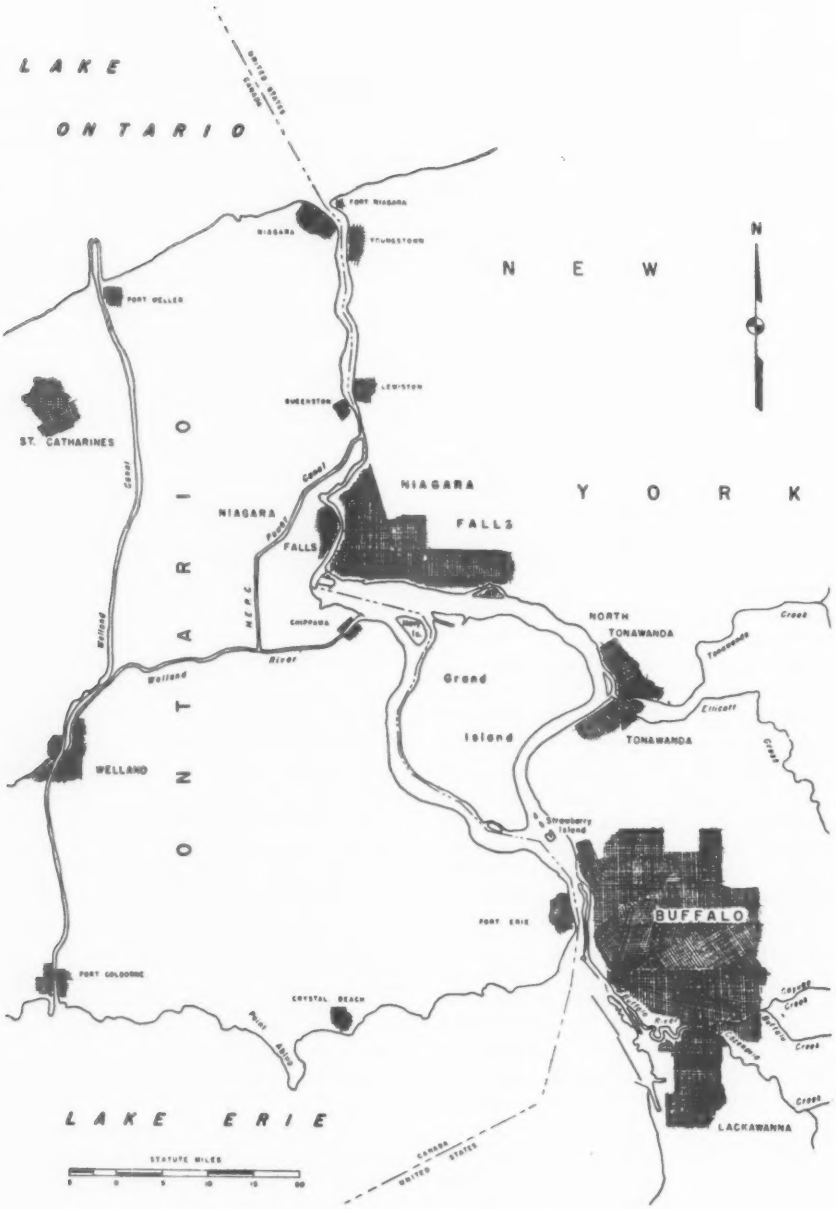


FIGURE 1.—General regional map of Niagara River.

Hydrographic Information

Niagara River serves as a connecting link, a spillway, from Lake Erie to Lake Ontario. In a total length of some 37 mi., by way of the east channel, the water level drops 326 ft., with one-half of this occurring midway at the falls. The upper river is divided by Grand Island, a 27-sq. mi. tract of land. Flow distribution has been determined as 43 per cent through the east channel and 57 per cent through the west channel. River distances around Grand Island are 13 mi. for the east channel and 9 mi. for the west channel.

Transition from Lake Erie to Niagara River is through a funnel-shaped section which narrows in a distance of about 1.5 mi. to a constricted channel in rock with a minimum width of 1,500 ft. and an average depth of about 17 ft., where current velocities as great as 10 m.p.h. (15 f.p.s.) occur. Navigation past these rapids is made possible by the Black Rock Canal, which parallels the river for 3½ mi. on the United States side.

The constricted channel continues for approximately 2 mi. and then gradually widens to 5,900 ft. at the head of Strawberry Island. According to the United States Lake Survey, the mean velocities at the head of Strawberry Island are 2.80 f.p.s. in the United States Channel and 2 60 f.p.s. in the Canadian Channel. The swiftest velocities in the river occur in the Whirlpool Rapids below the falls, where velocities as high as 30 m.p.h. (45 f.p.s.) have been estimated. The full diluting power of the river is probably first realized in this stretch.

The East or Tonawanda Channel commences at Strawberry Island, immediately upstream from the southern tip of Grand Island. A dredged channel 21 ft. deep lies east of Strawberry Island from Black Rock Canal to a point opposite Motor Island. From Motor Island to Tonawanda Island there is a natural average depth of 20 to 28 ft. The balance of the East Channel is comparatively shallow, with widths varying from 1,600 to 4,000 ft. A channel 12 ft. deep for vessel navigation is maintained through the downstream 8½ mi. of the East Channel to Niagara Falls, N. Y.

The International Boundary follows the West, or Chippewa Channel. This channel, used only by small craft, varies in width from 2,000 to 4,000 ft., and has depths from 15 to 30 ft. The West Channel divides at Navy Island and then recombines with the East Channel to form the large body of water upstream from the rapids above Horseshoe and American Falls.

The total catchment area above Niagara Falls is 265,095 sq. mi. This is exactly one-half the size of the Missouri River drainage basin. The average flow of Niagara River at its inlet from Lake Erie for the 90-year period from 1860 to 1949 was 202,000 c.f.s. The mean monthly flow ranges from 117,000 to 253,000 c.f.s. Cycles of precipitation and other meteorological factors cause a range in the annual mean discharge rate for the river of approximately 75,000 c.f.s.

The rate of flow in Niagara River is dependent almost entirely upon the water level of Lake Erie at Buffalo. Lake Erie is the most tempestuous of the Great Lakes, due to its position in relation to storm tracks and its shallow depth (mean depth of 90 ft.). Storms associated with local variations in atmospheric pressure create seiches which cause the lake level to fluctuate widely. A continuing east wind drops the lake level below the Low Water Datum (L. W. D.),* making it impossible, at times, for ships to enter Buffalo Harbor. On one occasion, the rock bottom at Fort Erie was reported exposed. Similarly, a continuing strong southwest wind has raised the level in the harbor as much as 11 ft.

* Low Water Datum is the level below which the lake should seldom go. It was established in 1934 for Lake Erie as 570.5 at Cleveland, Ohio.

above Low Water Datum. These major variations in lake level at Buffalo augment pollution of the boundary waters through purging of tributary streams.

Boundary Water Tributaries

Most of the industries in this area, requiring large volumes of water for cooling and process, are so located that water can be pumped from and returned directly to the boundary waters. The concentration of industries located along Buffalo River is the one exception. Tonawanda Creek, Buffalo River, and Ellicott Creek represent 87.5 per cent of the area in the United States draining directly to Niagara River. Ellicott Creek is actually a tributary of Tonawanda Creek, although their confluence is less than one-half mile from Niagara River. Some of the smaller tributaries likewise drain industrial areas and discharge significant wastes. The principal tributaries and their respective drainage areas are listed in Table I.

Buffalo River is one of the most significant tributaries from the standpoint of boundary water pollution. This stream is a dredged basin of some 165,000,000 cu. ft., extending from Buffalo Harbor to the confluence of Buffalo and Cazenovia Creeks, a distance of approximately 6 mi. Extremely low flows during the summer months make this stream virtually a pool. The lowest average monthly flow during the 8-year period 1943–1950 occurred in August 1949, when the average discharge was 47.4 c.f.s., which included 10 m.g.d. of Buffalo city water used by the industries. The minimum daily flows in Buffalo River are of even greater significance. The yearly low, daily discharge rates, exclusive of city water used and discharged by the industries, for three recent years were:

Date	Rate (c.f.s.)
August 24, 1941	9.2
September 18, 1948	10.3
August 27, 1949	12.3

Flood flow has been estimated as high as 27,000 c.f.s. Theoretical retention in the dredged portion is almost exactly two days for a discharge of 1,000 c.f.s.

Tonawanda Creek serves as the New York State Barge Canal between Niagara River and Pendleton, a distance of 12 mi. During the navigation season (April 1 to December 1) canal operations require 1,000 c.f.s., which normally exceeds the flow in Tonawanda Creek. This requirement causes reversal of flow in the lower reaches of the creek, resulting in flow of Niagara River water to the Barge Canal. Somewhat less water passes through the canal when it is closed to navigation, at which time most of Tonawanda Creek discharge is to Niagara River. Total flow from Tonawanda Creek to Niagara River occurs during a 1-month period each year when the canal is dewatered for inspection and repairs.

TABLE I.—Drainage Areas of Tributaries, in Square Miles

Stream	Niagara River	Lake Erie-East End
Buffalo River	424	—
Scajaquada Creek	22	—
Tonawanda Creek (Barge Canal)	530	—
Ellicott Creek	119	—
Cayuga Creek	34	—
Miscellaneous:		
Upper River	77	—
Lower River	19	—
Smokes Creek	—	33
Eighteenmile Creek	—	110
Rush Creek	—	11
Total	1,225	154

Buffalo River Project

During the period May to October, 1946, the Buffalo Sewer Authority, in cooperation with industry, made a comprehensive survey of Buffalo River and simultaneously examined the effluents from the five major industries contributing wastes to the stream. This survey resulted in a pollution abatement program, one phase of

which was a proposal now known as the Buffalo River Pollution Abatement and Industrial Water Supply Project (2).

The original plan contemplated a water system which would provide the five major Buffalo River industries with clean, cool, alkaline water direct from Lake Erie for process and cooling purposes. A system having an ultimate capacity of 180 m.g.d. was proposed. The proposed project had the further objective of creating sufficient flow in Buffalo River, during periods of dry-weather flow, to prevent concentration of waste in the stream, thus mitigating "slugs" of waste reaching Niagara River.

With the objective of expediting this project, an exploratory conference was sponsored September 19, 1952, at Buffalo by the New York State Joint Legislative Committee on Natural Resources and Interstate Cooperation. Representatives of the city of Buffalo, the five major industries located along Buffalo River, the New York Water Pollution Control Board, the New York State Department of Health, and other interested agencies participating in this meeting agreed that an engineering study should be made of this proposed water supply development.

The engineer's preliminary plans for this project have been completed and a meeting of representatives of the five industries with the Buffalo Sewer Authority has been arranged with a view toward determining the ways and means and under what terms this project can be undertaken. Members of the Joint Legislative Committee have expressed their desire to assist with any legislation that may be found necessary.

Uses of Boundary Waters

Knowledge of this area leads to the unequivocal conclusion that these boundary waters must have many and varied uses. The New York Water Pollution Control Law is predicated on this reality, and through classification the Water Pollution Control Board endeavors to establish best usage of waters in the public interest. Bases for recommended classification and assignment of standards of quality and purity for waters on the United States side of the International Boundary are contained in a Board report (3).

Testimony at public hearings held in Buffalo, N. Y., October 21, 1953, together with the comprehensive Board report referred to in the preceding paragraph, will serve as bases for classifications to be established by the Water Pollution Control Board.

Review of all data pertaining to the East Channel of the Niagara River, by the New York State Department of Health, revealed that no one of the seven adopted classes applied (4). Accordingly, a special class (Niagara River) has been proposed. The standards specified for this special class are consistent with the water quality objectives of the International Joint Commission. The next step in this program is formal classification of Niagara River and its tributaries by the New York State Water Pollution Control Board.

Regardless of what classification may be established, the present water requirements and water uses must continue to be satisfied. Domestic water supply receives first priority on boundary waters use. Approximately 935,000 persons on the United States side are presently supplied by municipal plants taking water from the east end of Lake Erie and Niagara River. In addition, the Falls attract some 3,000,000 visitors annually. High quality water requirements for certain industrial processes likewise establish a high priority for industrial water supplies.

An abundance of fresh water for process, low cost hydro-electric power, and lake transportation have been major factors in the industrial develop-

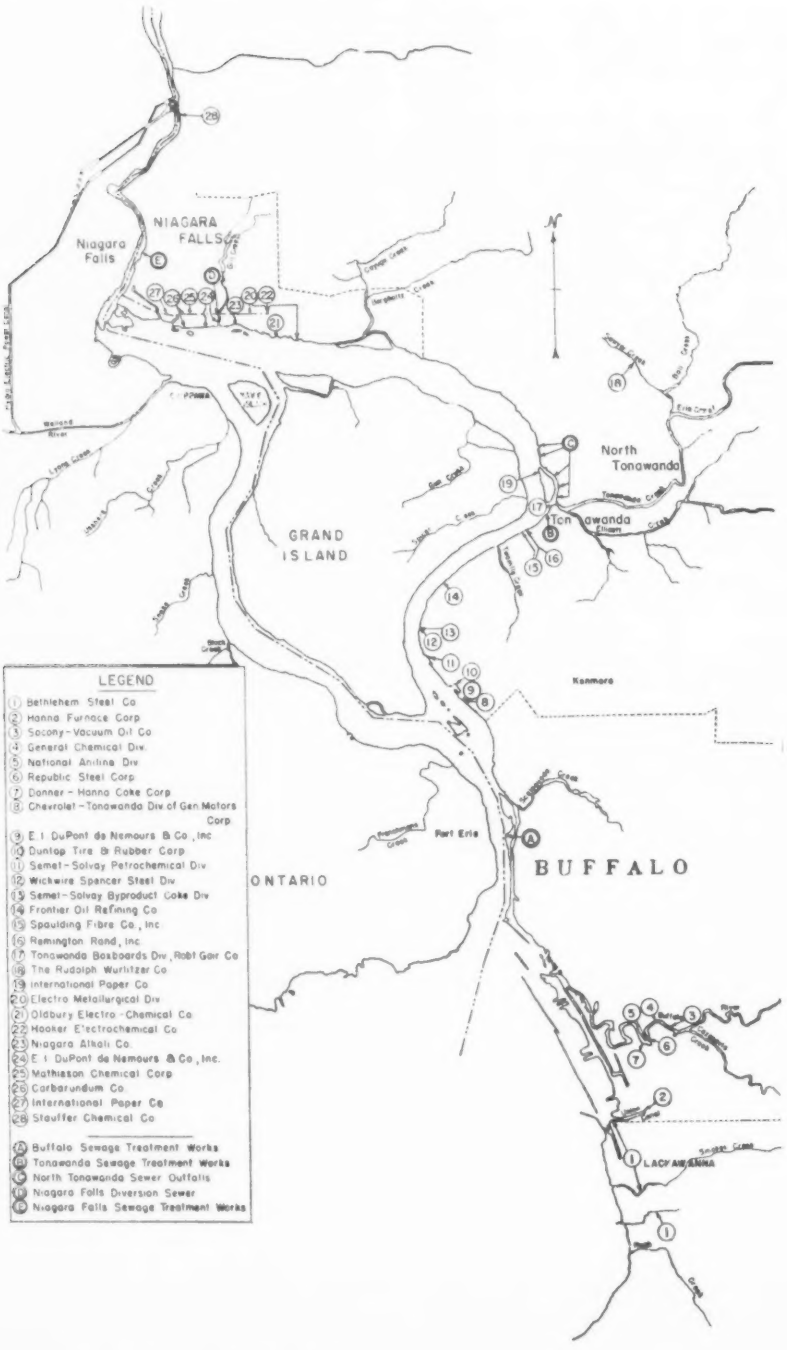

NIAGARA FALLS
Niagara Falls
GRAND ISLAND
North Tonawanda
Tonawanda
BUFFALO
ONTARIO
Kenmore
Port Erie
LACKAWANNA
LEGEND
(1) Bethlehem Steel Co.
(2) Hanna Furnace Corp.
(3) Socony-Vacuum Oil Co.
(4) General Chemical Div.
(5) National Aniline Div.
(6) Republic Steel Corp.
(7) Donner-Hanna Coke Corp.
(8) Chevrolet-Tonawanda Div. of Gen. Motors Corp.
(9) E. I. DuPont de Nemours & Co., Inc.
(10) Dunlop Tire & Rubber Corp.
(11) Semet-Solvay Petrochemical Div.
(12) Wickwire Spencer Steel Div.
(13) Semet-Solvay Byproduct Coke Div.
(14) Frontier Oil Refining Co.
(15) Spaulding Fibre Co., Inc.
(16) Remington Rand, Inc.
(17) Tonawanda Boxboards Div., Robt Gair Co.
(18) The Rudolph Wurlitzer Co.
(19) International Paper Co.
(20) Electro Metallurgical Div.
(21) Oldbury Electro-Chemical Co.
(22) Hooker Electrochemical Co.
(23) Niagara Alkali Co.
(24) E. I. DuPont de Nemours & Co., Inc.
(25) Mathieson Chemical Corp.
(26) Carborundum Co.
(27) International Paper Co.
(28) Stauffer Chemical Co.
(A) Buffalo Sewage Treatment Works
(B) Tonawanda Sewage Treatment Works
(C) North Tonawanda Sewer Outfalls
(D) Niagara Falls Diversion Sewer
(E) Niagara Falls Sewage Treatment Works

FIGURE 2.—Niagara River industrial and municipal outfalls.

ment and prosperous growth of this area. Public acceptance of the development of natural resources was further exemplified by the treaty of 1950, which virtually doubled the volume of water which can now be diverted from the Falls for power.

Concurrent with water supply, navigation, and power uses specifically mentioned in the treaty of 1909, these boundary waters must continue to receive treated domestic sewage and residual wastes from industry. This is recognized as an essential and legitimate water use. Likewise, fish and wildlife must be protected and the intangible recreational values must be preserved. These demands apply equally on either side of the International Boundary.

Principal Pollution Sources

Significant pollutional materials discharged to the boundary waters include untreated and partially treated domestic sewage, industrial wastes, intermittent release of sewage from both freight and passenger vessels, and the leaching from dredge dumps. To these must be added combined sewer overflows and the irregular discharge from tributaries and from Buffalo Harbor. Location of industrial sewer outfalls for the major industries and the points of discharge from the larger municipal sewer systems are shown in Figure 2.

Domestic Wastes

Discharge from municipal sewer systems has a place in this discussion because of the industrial wastes they receive. This is particularly true for the Niagara Falls and Buffalo sewage treatment works. Most of the sewers in the area are combined, receiving both storm water and sanitary sewage. There are numerous sewer overflows to tributaries and to Niagara River directly. During periods of excessive runoff, the flushing of sewers and overflows introduces a significant additional pollution load on the stream.

Based on the 1950 census, there are 1,038,000 people residing in the area draining to Niagara River and to the east end of Lake Erie. Of this total, 90 per cent are served by public sewer systems. Some degree of treatment has been provided for 97 per cent of the sewage from the sewered areas, but only 10 per cent receives complete treatment. The domestic sewage problem is beyond the scope of this paper but details are given in the Water Pollution Control Board Report (3).

Wastes from Vessels

Both passenger and freight vessels navigate the east end of Lake Erie and a considerable tonnage of freight is handled by the New York State Barge Canal. Passenger vessels operating into Buffalo are equipped with sewage holding tanks, but these are not presently provided on freighters. Sewage stored in the tanks is usually dumped shortly after departure from the harbor area.

Bilge and ballast water are frequently discharged from vessels. Bilge water includes seepage through the hull, and leakage from water lines, pumps, and machinery, and may contain some lubricating oils and greases. Ballast water is used to stabilize the vessel under various operating conditions and is taken on whenever and wherever needed. This requirement frequently transfers water from a polluted zone to a relatively clean area. The waste problem of vessels is complicated by the fact that they are usually on the move.

Dredge Dump Areas

The U. S. Army, Corps of Engineers, has established and uses two areas in these boundary waters for the dumping of dredged materials. These materials are a combination of rock, silt, sewage solids, and settleable solids from industrial wastes.

Dredged materials from Buffalo River, the entrance to Buffalo River,

the Outer Harbor, and Black Rock Canal are deposited in an area at the east end of Lake Erie adjacent to Bethlehem Steel Company property. The total area approximates ¾ sq. mi. Minimum water depth over the dumping ground is 6 ft. The south section of this dumping ground has been used for rock. In the past three years, material was taken to the rock dump for only a short period; the rest of the time the earth dump was used. It has been reported that this dumping area will be abandoned in 3 to 4 years.

The second dumping ground is located in Niagara River along the north shore of Grand Island and a tip of Buckhorn Island. This dump area is slightly over ½ mi. east and west and averages about ¼ mi. wide. Material dredged from Niagara River downstream from Tonawanda Island has been dumped in this area in the past. There has been no regular dredging of this channel for many years and only occasional removal of obstacles.

Location of the Lake Erie dredge dump ground is significant because of its proximity to the Erie County Water Authority water intake. (This water purification plant was formerly owned and operated by Western New York Water Company.) This intake line extends into the lake a distance of 4,425 ft. and parallels the south edge of the dump area at a distance of ⅞ mi. Furthermore, this dredge dump creates what amounts to a shallow bay at the outlet of Smokes Creek and serves as a barrier to natural flow along the lake shore in the direction of Niagara River.

Industrial Wastes

There are 32 major industries located along the Niagara Frontier known to have significant liquid wastes. Since these wastes are discussed in some detail in a subsequent section, only the general location of the industries is indicated here (see Figure 2).

There is a concentration of electrochemical, electrometallurgical, carborundum, and allied industries in the city of Niagara Falls. In addition, there are specialty paper mills and manufacture of synthetic organic chemicals.

The following types of industries are located in the Tonawandas: plastics, phenolic products, electroplating, textile, pulp and paper, petroleum refining, by-product coke, steel, oil gas, petrochemical, automobile tires, synthetic fiber, and automobile engines.

Buffalo has five large industries located along Buffalo River. These include a steel mill with two blast furnaces, by-product coke plant, petroleum refinery, acid plant, and one of the country's largest manufacturers of dyes, dye intermediates, and synthetic organic chemicals.

Along the east shore of Lake Erie in Lackawanna is one of the world's largest integrated steel mills. This includes by-product coke, blast furnaces, and rolling mills in a single plant. There are four additional blast furnaces in Lackawanna operated by another company.

Waste Control and Treatment

These industries have, for the most part, elected to solve their waste problems independently through process control and separate waste treatment systems. The character and volume of wastes have dictated this approach in several cases and in others municipal sewers have not been accessible. Profitable by-product recovery has solved several waste problems. Descriptions of the various methods employed by industry to curb pollution would require a series of technical papers and is beyond the scope of this discussion.

Determination of the efficacy of industrial waste control and treatment is a continuing program. One industry maintains an accurate record of effluent quality on an 8-hr. shift basis.

Another industry effectively employs ultraviolet absorption techniques in effluent control. The potential economies in positive industrial effluent control and the value of such records are becoming more and more evident.

Combined Treatment

The Buffalo Sewer Authority provides treatment for a variety of industrial wastes. Treatment consists of prechlorination, sedimentation, separate sludge digestion, and incineration of the dewatered sludge. Industries served include: rubber reclaiming, tanneries, meat packing, synthetic organic chemicals, and others. A special charge is made for trade wastes having chlorine demand and suspended solids significantly higher than the normal Buffalo domestic sewage. This surcharge is computed by a formula derived for the purpose (5). Digestion capacity of this plant is currently (1954) being increased 125 per cent and an elutriation unit is being installed.

The Niagara Falls sewage treatment works receives large volumes of clean cooling water and substantial amounts of process wastes from local industries. At one time, it was reported that 85 per cent of the flow was of industrial origin (6). Although a diversion sewer was constructed by the city to receive cooling water and innocuous or treated trade wastes, it has actually had limited use. In the past, trouble has been caused by obnoxious gases released from trade wastes discharged to the diversion sewer. For some of the industries, use of the diversion sewer or return of cooling water to the river requires pumping, whereas the city system permits gravity flow. The most serious operational problems at the treatment plant, caused by these industrial wastes, have been clogging the screens, obnoxious and dangerous gases, and erratic chlorine demand. Normally sewage entering the plant contains free chlorine, occasionally as much as 300 p.p.m. Conversely, at times the influent has had a chlorine demand of 100 to 200 p.p.m. Through cooperation of all concerned, these conditions have been much improved.

Pollutional Constituents Studied

The I. J. C. Boundary Waters Pollution Investigation of 1948–9 was designed to correlate recognized objectionable wastes with their effects on the receiving waters. Analytical determinations were selected with the hope of tracing the course of pollutional materials and of determining their persistence in those natural waters. This work was complicated by the limitations of analytical procedures for determination of specific constituents in extremely high dilutions. Industrial effluents were examined for suspected toxic materials even though these were not normally detectable in the stream.

Review of the analytical data contained in the I.J.C. 1951 report (1) indicates phenol and coliform bacteria to be the most significant determinations. These constituted positive parameters of pollution in that each had direct bearing on public water supplies and both persisted into Lake Ontario.

Tests for chlorine demand, odor, and iron were an aid in evaluating pollution and its effect on treatment of water for domestic use. Cyanide concentration was determined for industrial effluents containing cyanogen compounds because of their threat to aquatic life. Examination for oils was of special value in study of wastes from petroleum refineries, steel mills, and other large users of oil products. Determinations for suspended solids, acidity, and alkalinity were significant, even though the effect of these pollutants was usually localized in the vicinity of the contributing outfalls. The results for B.O.D. and ammonium com-

TABLE II.—Summary of Industrial Wastes Discharged Daily in 1949—United States Waters *

Area	Gibbs Phenol (lb.)	Cyanides, CN (lb.)	Ammonium Compounds, NH_3 (lb.)	Oils (U. S. gal.)	Suspended Solids (tons)	Acid Equiv. $CaCO_3$ (tons)
Lake Erie	155	175	1,750	990	130	37
Niagara River	5,045	1,545	1,165	1,530	305	55
Total	5,200	1,720	2,915	2,520	435	92

* Based on I. J. C. and supplementary data.

pounds were a further aid in appraisal of pollution.

Quantities of industrial wastes determined as a part of the 1948–9 I.J.C. studies are recorded in Table II. Similar data, based on recent reports from industry, are tabulated for comparison in Table III. Intermittent discharge of phenol has been reduced to daily basis in order to give a true picture of the total amount entering the river. This conceals the peak rates of discharge for the phenol-bearing wastes. The cyanide data do not include electroplating wastes, inasmuch as these plants were not surveyed in 1949.

Phenolic-Type Materials

The primary sources of phenolic-type materials in this area are by-product coke plants, manufacture of phenolic resins, and the catalytic cracking of petroleum. Secondary sources include oil-gas generators and sewage treatment plants receiving trade wastes; effluents from both the Buffalo and Niagara Falls plants contained phenol in 1949. One significant phenol discharge to Buffalo River has recently been eliminated by substitution of a new process. Because of the offensive character of phenol in extremely high dilutions, traces of phenol have been reported.

By-Product Coke—Three by-product coke plants in the Lackawanna-Buffalo-Tonawanda area have a combined capacity for carbonizing 17,100 tons of coal per day. In December 1953, these coke plants averaged 90 per cent capacity, which was comparable with operation during the 1948–9 studies. This represented 15,400 tons of coal carbonized and production of 10,800 tons of coke daily.

Two of the coke plants operate mostly on blast furnace coke, at relatively high coking temperatures, thus producing a minimum of phenol. The third plant produces both domestic and blast furnace coke. The latter plant recovers ammonia by the indirect process and accordingly makes considerably more phenol per ton of coal carbonized than either of the other two (7).

Bethlehem Steel Company has dephenolized ammoniacal liquor for some 25 years at the Lackawanna mill.

TABLE III.—Summary of Industrial Wastes Discharged Daily in 1953—United States Waters

Area	Gibbs Phenol (lb.)	Cyanides, CN (lb.)	Ammonium Compounds, NH_3 (lb.)	Oils (U. S. gal.)	Suspended Solids (tons)	Acid Equiv. $CaCO_3$ (tons)
Lake Erie	100	175	590	990	60	37
Niagara River	4,185	560	1,450	1,720	205	23
Total	4,285	735	2,040	2,710	265	60

This company installed a benzol extraction phenol recovery system during 1953. The new unit has greater capacity and is more efficient than the dephenolizing system it replaced. The other two by-product coke plants do not presently dephenolize. By-product coke phenol and phenolic equivalents, including the residual from Bethlehem Steel Company, amounted to 3,120 lb. per day, or 73 per cent of the total phenol being discharged during 1953 to the International Boundary Waters and tributaries.

Plastics—Production of phenol-formaldehyde-type resins at two plants located in the Tonawandas results in the second major source of phenol. In the manufacture of these resins a distillate is produced during the dehydration stage which contains (depending on the resin being produced) 2 to 8 per cent phenol. This is a batch operation and the distillate is collected in storage tanks for gravity separation of resinous material.

One plant operates an efficient benzene extraction system for recovery of phenol from the distillate (8). The recovery system is operated 5 days per week, with an average efficiency of 96 per cent. Improvements are being made which will increase the efficiency of this phenol recovery unit to 99 per cent. This plastics plant also manufactures phenol by the regenerative or catalytic vapor-phase process, but there is little phenol loss from this operation.

The other plastics plant provides long-time storage of the distillate, but does not dephenolize. Phenolic waste from this plant is drained once a week over an 18-hr. period. When the benzene extraction phenol recovery plant is operating and the second plastics plant is draining settled distillate, the combined phenol discharge rate from these two sources amounts to 2,035 lb. per 24-hr. day.

Petroleum Refining and Oil-Gas—Two petroleum refineries process approximately 50,000 bbl. of crude oil per day. Both operate catalytic cracking units, which produce somewhat more phenolic materials in the cracked gasoline than thermal cracking. Spent caustic containing high phenol concentrations is excluded from the sewers at each refinery.

There are four oil-gas generators in the Buffalo-Tonawanda area with a total capacity of 22,000,000 cu. ft. of gas per 24-hr. day. Three generators are standby units used to supplement natural gas during peak demand. The fourth unit operates continuously, supplying oil-gas for a petrochemical plant. Phenolic wastes presently discharged from the two refineries and the oil-gas generator amount to 350 lb. per day.

Municipal Sewage Plants—The Buffalo sewage treatment works effluent contained 75 lb. of phenol and the Niagara Falls treatment plant effluent 275 lb. of phenol per day at the time of the I. J. C. field studies in 1949. The significance of this phenol is the fact that it represents chlorophenol compounds. Chlorine is applied at both treatment plants for disinfection.

Cyanide

Cyanide was present in varying concentrations in the wastes from the following types of plants: by-product coke, electrometallurgical, electrochemical, blast furnaces, and electroplating. Analytical work was confined to the cyanide radical and reported as CN.

By-Product Coke—The principal cyanogen compound in coal gas is hydrogen cyanide (HCN). Hydrocyanic acid is an extremely water-soluble compound and may be expected in water condensed from the gas or water that has been in contact with the gas.

The most potent source of hydrogen cyanide in coke plant wastes is the gas final cooler water. It is common practice to re-use this cooling water by means of closed systems and cooling

towers. When the cooling tower is in operation, this source of cyanide is eliminated except for possible leaks, overflow, or draining of the system. The two coke plants employing semi-direct ammonia recovery have closed systems for the gas final cooler water.

The indirect ammonia recovery system, used by the third coke plant, provides adequate cooling of the gas in the counterflow ammonia scrubbers, thereby obviating the need for final coolers ahead of the light-oil scrubbers. However, the ammoniacal liquor from the indirect system absorbs more HCN from the gas than it does in the semi-direct process because of the lower temperature and greater volume (7). Some of this cyanide carries through into the ammonia still waste. This coke plant produced 0.038 lb. cyanide (CN) per ton of coal carbonized, as compared to 0.007 lb. for one of the other plants employing semi-direct ammonia recovery.

Total cyanide discharged from the three coke plants in 1949 averaged 215 lb. daily. Concentrations in the effluents varied between 0.6 and 1.5 p.p.m. CN. Most of this cyanide originated in the ammonia still waste and condensates at the benzol departments.

Electrometallurgical—The largest single source of cyanide in the area was the carbide and ferro-alloy furnaces gas scrubber water at Niagara Falls, which contained HCN concentrations as high as 20 to 30 p.p.m. This amounted to 720 lb. of cyanide (CN) daily. Alkaline chlorination is being used to reduce this cyanide to nitrogen and carbon dioxide.

Electrochemicals—The 1949 studies indicated 400 lb. of CN in the wastes from an electrochemical plant located in Niagara Falls. This plant manufactures a large number of end products, among which are metallic cyanides and sulfocyanides.

Production of sodium cyanide requires water for scrubbing gas emanating from the reaction vessels and for cooling the casting machine molds. In these operations, water comes in contact with traces of the product. Although a portion of the sodium cyanide production has been transferred to another plant, this process still contributes some cyanide waste.

Metallic cyanides and sulfocyanides are manufactured by standard aqueous processes consisting essentially of double decompositions and addition reactions. Water is used in these processes for dissolving raw materials, washing during filtering operations, and scrubbing vapors coming off the reaction vessels. Process modification and more accurate control have substantially reduced the cyanide concentration of these wastes. Based on improvements reported, it was estimated that cyanide losses from this plant during 1953 did not exceed 150 lb. of CN daily.

Blast Furnaces—Blast furnace flue gas wash water contains relatively low concentrations of HCN as compared with carbide and ferro-alloy electric furnaces. Data from two studies indicate a range of 0.16 to 2.2 p.p.m. HCN. Furthermore, blast furnaces use much less water in the wet scrubbers per 1,000 cu. ft. of gas than the electric furnaces. Considering capacity production of pig iron for the area, this source would give 275 lb. of CN daily.

Electroplating—Several industries in the area operate metal-finishing departments. Two of the larger plants were visited to observe waste control procedures, but no studies were made. These plants used sodium, copper, and zinc cyanides in conventional plating operations. Both automatic and semi-automatic electroplating machines were in service.

Consideration had been given to reduction in dragout and to minimizing loss of useable plating materials. Sludge accumulating in plating tanks was reported removed routinely and disposed of at the city dump. Plating

chemicals were replenished when necessary and the solutions were being used indefinitely. Rinse waters were the only waste discharge reported from the plating departments visited. Cognizance had been taken by plant officials and operators of the highly toxic character of plating solutions. Information obtained indicated these metal-finishing establishments to be minor sources of cyanide.

Ammonium Compounds

Significant industrial sources of ammonia were the by-product coke plants and plastics manufacture. These were relatively minor, however, as compared with the ammonia in the treated domestic sewage. At the time of the I.J.C. field studies in 1949, the Buffalo and Niagara Falls sewage plant effluents contained more than five times as much ammonia as the industrial wastes from the area. Free ammonia and ammonium salts were determined.

The high ammonia losses in the Lake Erie area during 1949 indicated only partial recovery of fixed ammonia from the ammoniacal liquor at the Lackawanna coke plant. Recent study of the effluent from this plant has shown marked reduction in ammonia loss. The wastes from one plastics manufacturing plant surveyed in 1949 contained 380 lb. of ammonia (NH_3) daily.

Oils and Greases

Petroleum refineries, steel rolling mills, and a plant producing automobile engines were the principal contributors of oily wastes. There were numerous other sources of lesser importance. Increase shown for oil losses (Tables II and III) was caused primarily by sludge accumulation and reduced retention in one of the refinery master oil-water separators. Oil losses would be considerably higher if it were not for recent improvements. Some of the most significant developments are as follows:

1. New oil-water separator. One refinery placed a new A.P.I. master oil-water separator in operation during September 1953. This separator is of the latest design, incorporating the open-channel approach and a vertical-slot baffle-type inlet to give uniform unidirectional flow. The unit has two single-stage chambers in parallel, each equipped with flight scrapers and facilities for sludge and oil removal. A company report for separator effluent analysis showed 46 p.p.m. total oil.

2. Water-lubricated bearings. Progress has been made in steel mills in reducing oil losses by use of water-lubricated composition bearings in lieu of oil-lubricated bearings. A new blooming mill installed in 1951 was equipped in large part with the water-cooled type bearing. As operations permit, installation of bearings of this type will be continued in the finishing mills. Recently a large number of table roll bearings in these mills have been changed from oil to grease lubrication, which further minimizes loss to sewers.

3. Automobile engine oil waste. Oils wasted from the automobile engine factory, amounting to 545 g.p.d., were approximately two-thirds soluble and one-third insoluble. Wastes high in insoluble oil were passed through a two-compartment, baffled, gravity, oil-water separator, which removed as much as 96 per cent of the separable oil. The insoluble oil in the plant discharge originated in this separator effluent and in larger volumes of waste water throughout the factory. An oil treatment and recovery system presently under construction will provide efficient removal of both soluble and insoluble oil from the wastes of this plant.

4. Soluble oil recovery. A very effective oil waste treatment system has recently been placed in service at an aviation engine plant in the town of Tonawanda. These wastes include miscellaneous machine oils, soluble cutting oils, and emulsion cleaners, all collected by a separate sewer system. This treatment system provides grav-

ity oil-water separation, treatment with alum and sulfuric acid to give pH 4.25, mixing and flocculation, 4-hr. settling, addition of caustic to maintain the pH between 5.5 and 6.0, and a Colloidair separator. Effluent from the Colloidair unit averages less than 30 p.p.m. of oil.

Suspended Solids

There was perhaps no pollutional constituent more common to these industries than suspended solids. Of the 32 industrial plants studied, 24 (75 per cent) discharged significant quantities of suspended solids. Four industries produced 92.5 per cent of these solids. These were: steel, pulp and paper, electrometallurgical, and electrochemical. The remaining 7.5 per cent originated in a miscellaneous group.

Reports from industry indicate an over-all reduction of 39 per cent in suspended solids discharged to the boundary waters and tributaries during the past five years (Tables II and III). The 170 tons reduction does not reveal the increase in suspended solids in liquid wastes brought about by installation of gas wet scrubbers for air pollution control.

Steel Industry—Included in this group are blast furnaces, by-product coke plants, and steel rolling mills for the entire area. Iron ore, coke fines, and mill scale are the principal suspended solids in the wastes from these plants. Solids from the steel industry amounted to 230 tons in 1949, which tonnage was 53 per cent of the total discharged to the boundary waters.

Solids from blast furnace flue gas wash water and mill scale, when dewatered and sintered, comprise valuable material which is suitable as a portion of the blast furnace charge. These solids settle readily, but efficient recovery requires sedimentation units with provision for concentrating and dewatering the sludge. Efficient thickeners will recover in excess of 96 per cent of blast furnace solids and produce a 35 to 45 per cent moisture sludge. Vacuum filtration further reduces the moisture content. If the filter cake approaches 18 per cent moisture it is acceptable for sintering; otherwise it must be stockpiled and allowed to air dry.

During the past four years, clarifiers and thickeners have been installed to provide efficient recovery of solids from the blast furnace gas wash water for furnaces located in Lackawanna. Prior to 1950, a portion of these solids was recovered in short-time settling basins and watertight sludge cars routinely cleaned by a clamshell dredge. The more efficient recovery has removed an additional 115 tons of suspended solids daily from the boundary waters. In addition, positive means are now available for concentrating and dewatering the sludge. Recent expenditures totaling some $2,500,000, by the two Lackawanna blast furnace departments for solids recovery, are reported to be sound investments.

Pulp and Paper—This industry discharged 88 tons suspended solids daily to the boundary waters in 1949, representing 20.3 per cent of the total. These solids losses are high because of the volume of reclaimed paper stock used as raw material by one mill. Through extensive modernization of one mill and reduced water consumption at another, paper mill solids have been reduced 5 tons per day.

Electrometallurgical—Carbide and ferro-alloys are produced in electric furnaces. Many of these furnaces are covered and the furnace gases with entrained dust particles are removed by wet scrubbers. The water from these scrubbers constitutes the principal liquid waste from this industry.

During the past five years, suspended solids from these wet scrubbers increased from 37.6 to 81 tons daily. This 115 per cent increase was brought about by installation of additional scrubbers to reduce air pollution. Most of these wastes (8.1 m.g.d.) are now

passed through a 130-ft. diameter clarifier, which was placed in service late in 1949. This unit removes approximately 64 tons solids daily for an average efficiency of 97 per cent. The effluent, carrying some 0.5 ton of suspended solids, drains to Niagara River. Sludge from the clarifier has no value and is lagooned. Wastes not yet diverted to the clarifier and containing about 16.5 tons of suspended solids daily are discharged to sewers leading to the Niagara Falls sewage treatment works.

Electrochemical—Suspended solids in the liquid wastes from four manufacturing plants of the electrochemical industry amounted to 46 tons daily in 1949, which was 10.7 per cent of the total reported for the area. One plant accounted for 88 per cent of these solids. Through development and process modification these solids, which are largely inert, have been reduced to 14 tons per day.

Miscellaneous—There were eight manufacturing plants in this group discharging some 32 tons of suspended solids per day (7.5 per cent of the total) in 1949. Three industries—synthetic organic chemicals and dyes, carborundum, and synthetic fiber—produced 92 per cent of these solids. Some improvements have been made, but their effect has been offset by increased production. It has been estimated that solids losses from these combined sources has actually increased 5 per cent.

Acids

Acid wastes were significant in the effluents from nine manufacturing plants. The primary source was spent pickle liquor from the steel industry. Other major sources included the wastes from manufacture of synthetic organic chemicals, synthetic fibers, and spent sulfuric acid used in drying chlorine gas. Free acid and hydrolyzable sulfate have been converted to calcium carbonate equivalent (Table IV).

TABLE IV.—Acids Discharged Daily to United States Waters; 1949

Plant	Materials Discharged		$CaCO_3$ Equivalent[1] (lb./day)
	Type	(lb./day)	
A[2]	H_2SO_4	6,285	6,400
	$FeSO_4$	103,000	67,700
B	H_2SO_4	3,680	3,760
C	H_2SO_4	33,600	34,300
D	H_2SO_4	650	665
E	H_2SO_4	22,700	23,200
F	H_2SO_4	23,900	24,400
G[2]	H_2SO_4	1,125	1,150
	$FeSO_4$	10,480	6,890
H	H_2SO_4	284	290
I[3]	H_2SO_4	1,730	1,770
	$FeSO_4$	16,100	10,600
	HCl	1,690	2,310
Total	—	—	183,435

[1] Computed on basis of sulfate.
[2] Intermittent dumping converted to daily basis.
[3] Based on acid consumption.

The steel industry was accountable for approximately 50 per cent of the acid wastes in this area in 1949. In the meantime, total acids discharged have been reduced about 35 per cent. This has been accomplished largely by process changes, improved control, and neutralization. Some plants have both caustic and acid wastes; others neutralize with lime. Spent pickle liquor now constitutes roughly 75 per cent of the total.

Steel was pickled in both batch and continuous equipment. Spent pickle liquor from batch operations was dumped over relatively short periods. This practice results in intermittent acid concentrations in the receiving waters substantially above those indicated by the average daily discharge. Furthermore, the iron content of these acid wastes may impair the receiving

water for both domestic and industrial uses.

Automatic flame scarfing has been substituted for pickling of certain steel products at one mill. This does not eliminate pickling, because scarfing is not applicable to all steel products. However, generation of acetylene required by the scarfing machine produces a calcium hydroxide slurry. This basic material is then available to neutralize the spent pickle liquor from those steel products that must be acid cleaned. For this particular mill, caustic waste exceeds that required for neutralization of the free acid in the spent pickle liquor.

An acid manufacturing plant has achieved marked reduction of acid losses through physical improvements, instrumentation, and vigilant control. Improvements included replacement of obsolete and worn-out equipment, use of more acid-resistant materials, and electrical facilities which minimize power failures. This is an excellent example of pollution abatement by improvements within the plant, and control.

Caustic Wastes

Large-scale production of chlorine by the electrolysis of solutions of sodium chloride results in caustic wastes which impart a high pH to several industrial effluents at Niagara Falls. In addition, generation of acetylene from calcium carbide results in a slaked lime slurry waste of some significance in the same area. The former waste has been reported to raise the pH of the river water, in the immediate vicinity of discharge, sufficiently to interfere with coagulation of water taken through nearby shore intakes and treated for industrial use.

Biochemical Oxygen Demand

The B.O.D. determination was made on those wastes containing significant quantities of decomposable organic matter. Some of these wastes also contained such reducing substances as sulfides and ferrous compounds which exerted an immediate chemical oxygen demand. The B.O.D. data were of greatest value in studying oxygen relationships for tributaries to the boundary waters. The diluting capacity of Niagara River reduced the dissolved oxygen deficit to a negligible value.

The two largest contributors of wastes high in oxygen demand are the pulp and paper industry and plants manufacturing synthetic organic chemicals, dye intermediates, and dyes. These industries are responsible for well over 60 per cent of the B.O.D. discharged to the boundary waters and tributaries. Some of these wastes are discharged to Buffalo River and others enter Niagara River at the Tonawandas and Niagara Falls. A considerable quantity of these wastes enters the Niagara River below the falls through the Edward Dean Adams power station tailrace and the Niagara Falls sewer system.

Miscellaneous

Chlorine demand, taste, and odor results were of greatest value in appraising the effect of industrial effluents on public water supplies and water treatment. Erratic chlorine demand in surface water received at municipal water purification plants constitutes a real public health hazard in that some water may reach the consumers with inadequate disinfection.

The non-specific taste and odor tests are a catch-all for many substances which have not been identified or for which suitable analytical determinations have not been perfected. They are invaluable as an aid in producing a potable water and occasionally can be used to trace taste- and odor-producing compounds to their source.

New Parameters

Standard methods were employed in all analytical work. These results gave a reasonably satisfactory measure

of the pollutional effect of these industrial wastes. Cognizance was taken of the fact that much remains to be learned about certain specific wastes, as well as their combined effect on the receiving waters. It is probable that further research on the various wastes and new or modified test procedures will reveal more significant parameters of pollution in the future.

Effect on Boundary Waters

Samples were collected at strategic points in the boundary waters during the 1948–9 studies, with the objectives of determining their sanitary quality and, insofar as possible, establishing the pattern of dispersion for pollutional materials. Water, as received at municipal intakes, was also routinely analyzed during the survey and again in the spring of 1952. Because of its persistence, phenol has been used to show the course of travel for pollutional materials.

Meteorological conditions and rates of discharge from tributaries are of extreme importance in studying pollution of and interpreting analytical results for these boundary waters. This was mentioned under "Hydrographic Information," but is re-emphasized here. Monthly climatological summaries for the Buffalo, N. Y., airport, prepared by the U. S. Weather Bureau, have been reviewed in an endeavor to correlate observations in the east end of Lake Erie and the upper Niagara River with wind velocities and direction, and precipitation. Water supply papers of the U. S. Geological Survey were the source of tributary flow data. In examining these data, cognizance must be taken of the fact that sampling by boat was not feasible during high winds and severe storms. An attempt was made to evaluate the increase in pollution load and the greater dispersion, during and following storms, by sampling from bridges and at water purification plants.

During the 15-month period from July 1, 1948, to September 30, 1949, there were 18 days when the wind attained a velocity of 40 m.p.h. or more. The maximum velocity recorded was 52 m.p.h., which occurred January 19, 1949. The wind direction was from the southwest each time the maximum velocity was recorded, with two exceptions; once the wind direction was from the west and the other time from the northwest.

Dilution

The results of subsurface float studies, conducted along the east shore of Lake Erie and reported in 1910 (9), showed littoral currents and currents some distance from shore normally moving in a northerly direction toward Niagara River. These same studies indicated that lake water flowed into Buffalo Outer Harbor through the south, middle, and north entrances. This direction of flow would normally prevent wastes discharged into the Outer Harbor from mixing with the main body of lake water.

Conditions along the east shore of Lake Erie are somewhat different in 1954 than they were in 1910. The south entrance to the Outer Harbor has been altered by a 2,000-ft. extension of the south breakwater. The more recent dredge dump area, previously described, would be expected to impede natural flow along the lake shore toward Niagara River. Furthermore, sustained high wind would cause polluting materials, discharged along the shore, to penetrate more deeply into the lake.

Lateral mixing in the upper portion of Niagara River increases with increase in flow from Buffalo River. This effect is minimized in the high velocity section of the river paralleling Black Rock Canal. It becomes more pronounced in the river section approaching the International Railroad Bridge crossing at Squaw Island and continues into the east channel. This increase in lateral mixing can be readily detected by turbidity and color

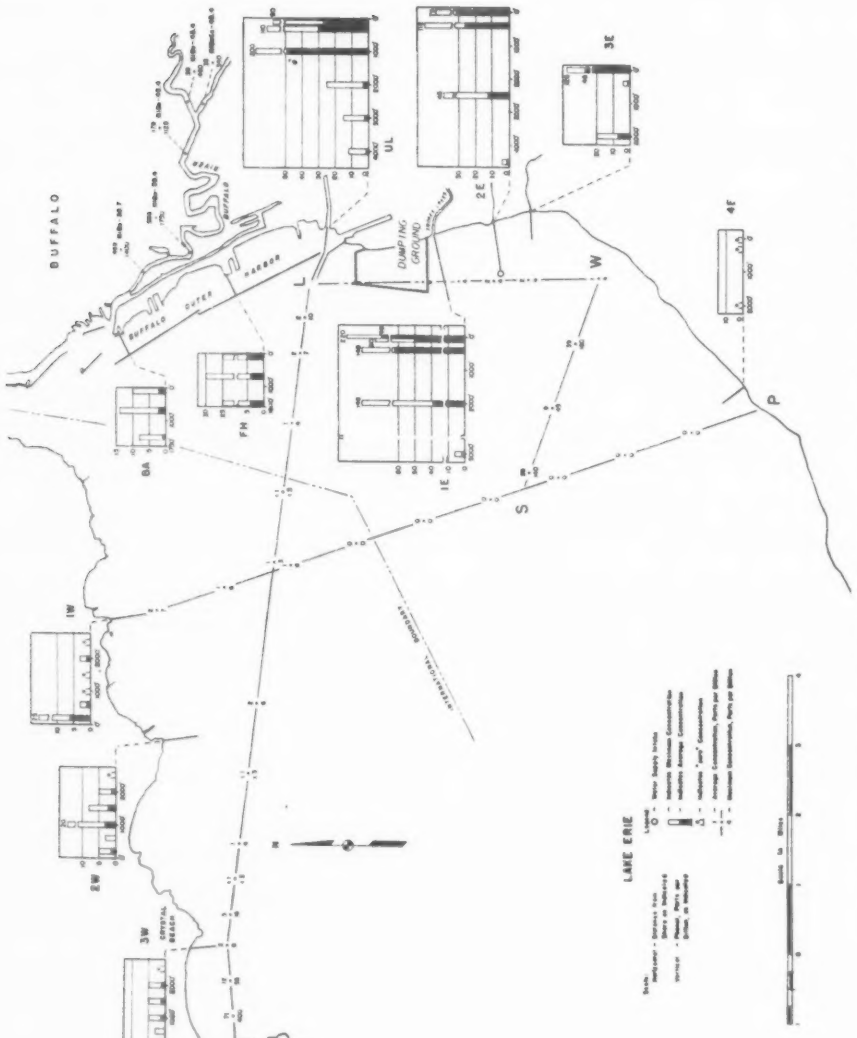


FIGURE 3.—Average and maximum phenol concentrations in east end of Lake Erie.

contrast with the cleaner Lake Erie water, the line of demarcation being visible for several miles. In the numerous studies made by various agencies over a long period of years, there has never been any evidence or data obtained indicating that this expanded zone of pollution significantly affected the west channel.

Perhaps the most important consideration in studying the upper Niagara River is the relatively small portion of the total flow available for dilution. There is a strong tendency for tributary, industrial, and municipal discharges to follow and remain along the shore. This condition is highly significant in disposing of acids and toxic materials requiring dilution to render them innocuous.

Lake Erie

Sampling on ranges LC, WS, LW, and IW–P was confined to September and October 1948, and to May, June, and July 1949. It was possible to sample in the Outer Harbor as late as December and as early as April. Maximum and average phenol concentrations are shown graphically in Figure 3.

The highest phenol values along the east shore of Lake Erie occurred in the vicinity of the mouth of Smokes Creek. Ranges 1E, 2E, and 3E all showed relatively high phenol concentrations more than 2,000 ft. from shore. Residual by-product coke wastes were a major source of phenol along the east shore and in the Outer Harbor.

Maximum phenol values observed on range WS were of particular interest. Phenol was found in only 4 of 15 samples collected on this range, but in each of these 4 the concentration was relatively high. The following information supplements that recorded in Figure 3:

Range WS

Date (1949)	Distance from U. S. Shore (mi.)	Phenol (p.p.b.)
May 11	1.4	160
May 11	2.4	45
May 17	1.4	35
May 17	3.4	140

Lake-water temperatures during this 7-day period ranged from 8° to 12° C. Water depth in this part of the lake averages about 30 ft., which may result in temporary thermal stratification of the warmer industrial discharges. Travel of pollution into the lake in this instance was attributed primarily to prevailing east winds. Unfortunately, range WS terminated 3.4 mi. from shore. Inasmuch as the phenol concentration at this point was 140 p.p.b. at the time of sampling, it is reasonable to suppose that phenol penetrated beyond this point in the lake.

Of a total of 83 samples collected on range LC, 29 (35 per cent) showed phenol. Excluding the three high values, phenol concentrations ranged between 3 and 10 p.p.b. The high phenol concentrations in the Crystal Beach area cannot be satisfactorily explained from available data. It is entirely possible that further investigations may reveal contributing sources of phenol not now recognized. However, the analytical data demonstrated that phenol existed along both the United States and Canadian shores and permeated the east end of Lake Erie during the period of the I.J.C. field study. Furthermore, under certain meteorological conditions, there was positive evidence of rapid dispersion and deep penetration of significant phenol concentrations into the lake. These observations serve to explain the occasional presence of phenol in low concentrations in the west portion of the upper Niagara River above Grand Island and in the west channel. The persistence of phenol in clean water lends credence to this hypothesis.

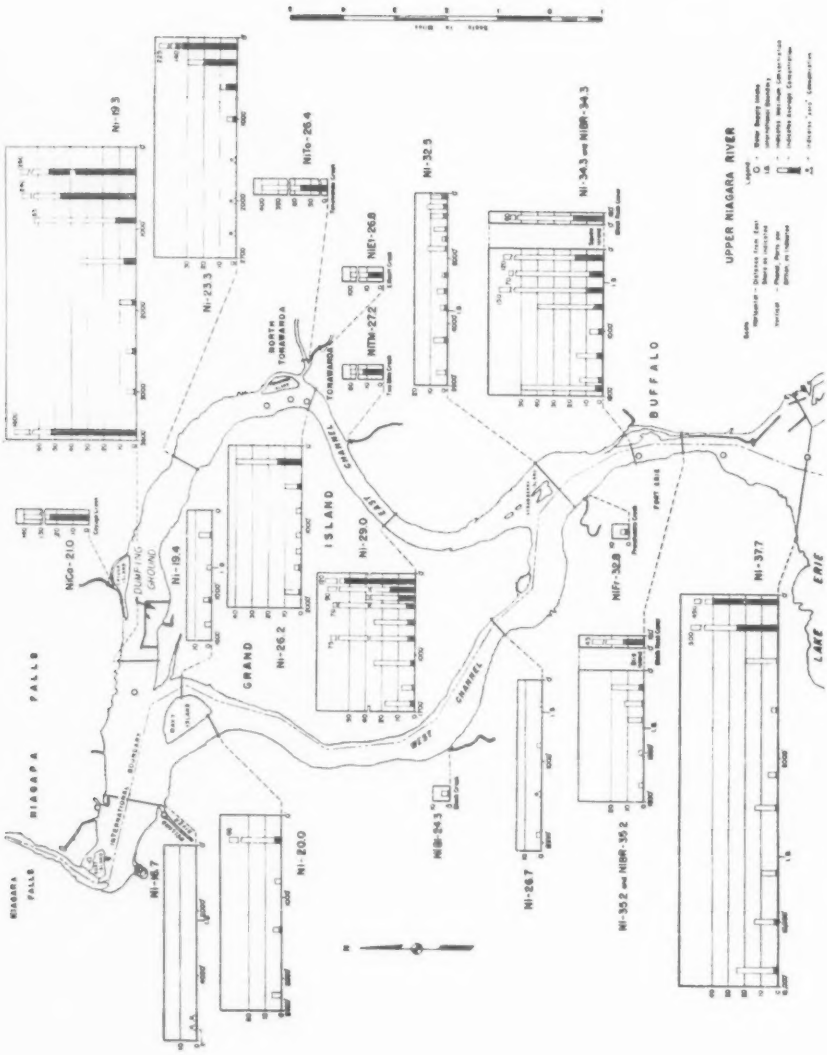


FIGURE 4.—Average and maximum phenol concentrations in upper Niagara River.

Upper Niagara River

Routine sampling of the Upper Niagara River was initiated in August 1948 and continued into July 1949. It was necessary to suspend sampling by boat during January, February, and March, but river sampling from bridges was intensified during the winter months. The International Railroad Bridge at Squaw Island and the two Grand Island Bridges across the east channel were used. Average and maximum phenol concentrations are plotted in Figure 4.

A mileage index system was used to identify river sampling ranges. This system involved the use of the letter Ni, followed by a number representing the distance in river miles from the mouth of Niagara River. The zero mileage point was taken 1 mi. from the mouth of the river in Lake Ontario at a bell buoy (B–1) established by the U. S. Coast Guard. Distances from this zero point were measured via the east channel around Grand Island.

Range Ni–37.7 was located just below confluence of Buffalo and Niagara Rivers and Buffalo Harbor, and extended to the Canadian shore in line with the city of Buffalo water intake. The maximum concentrations occurred April 7, 1949, following moderate rainfall the day before. Considering phenol results for Buffalo River, which were as high as 3,600 p.p.b. at the mouth December 22, 1948, it is probable that these values do not represent the most adverse conditions. The phenol that showed up at each sampling point on this range confirms phenol that was found dispersed through the east end of Lake Erie.

Figure 4 is especially interesting in that it illustrates the pollution pattern for that section of the boundary waters receiving the bulk of the wastes. The east end of Range Ni–35.2 was at the ferry dock immediately upstream from the Buffalo sewage treatment works. Sampling on this range was complicated by the high stream velocities. The phenol for this cross-section illustrates clearly how narrow the band of pollution normally is in this upper reach of the stream. The sampling point 200 ft. from the Bird Island shore was usually beyond the zone of pollution, as indicated by the fact that 10 out of 21 samples showed zero phenol and 5 others had only a trace. The maximum value of 20 p.p.b. at a distance 200 ft. from shore occurred September 21, 1948. Rainfall on September 19, 1948, amounted to 2.09 in. and on September 20, 0.86 in. The sampling point 400 ft. from shore showed zero phenol on September 21.

Range Ni–34.3 was the International Railroad Bridge at Squaw Island. A total of 262 samples was collected on this range during the period September 2, 1948, to July 4, 1949. Sampling during adverse weather and following storms revealed increased lateral mixing. The 40 p.p.b. phenol 700 ft. from the Squaw Island shore indicates that under certain conditions the pollution zone may cover 40 per cent of the width of the river at this point. The results for this range probably show the effect of the purging of Buffalo River as well as any river data obtained. However, extenuating circumstances occasionally prevented sampling at the most opportune time and these data do not necessarily show the heaviest pollution.

The low phenol results for range Ni–32.5, at the head of Strawberry Island, reflect both dilution and fair-weather sampling. The maximum values were obtained September 20, 1948. This followed a 2.09-in. rain on September 19. This was preceded by another storm period September 7 to 9, when a 2.57-in. rainfall was recorded. The earlier runoff would have a cleansing effect on tributary streams, thereby minimizing pollution from this source at the time of the September 20 sampling.

The South Grand Island Bridge was

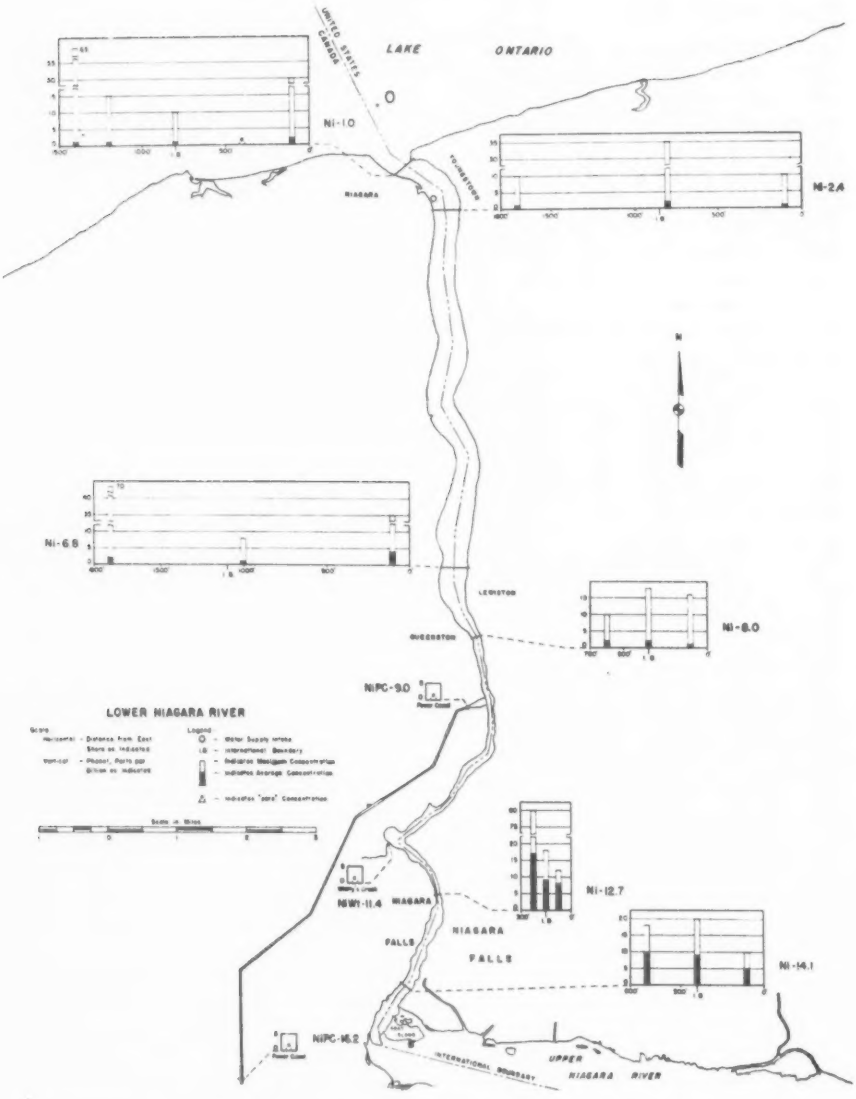


FIGURE 5.—Average and maximum phenol concentrations in lower Niagara River.

range Ni–29.0. A by-product coke plant that does not dephenolize ammoniacal liquor was located approximately 1 mi. upstream. This phenol source undoubtedly accounted for the high concentrations out 400 ft. from shore. The maximum phenol of 75 p.p.b. at a distance of 800 ft. from the east shore, occurring March 10, 1949, would appear to originate farther upstream.

There were other sources of phenol in the Tonawandas which accounted for high phenol found in the east por-

FIGURE 6.—Average and maximum phenol concentrations in west end of Lake Ontario.

tion of the river on downstream ranges. There was no explanation for the 1,600 p.p.b. phenol found 100 ft. from the south shore June 3, 1949, at the North Grand Island Bridge, Range Ni–19.3.

Lower Niagara River

Sampling in the lower river was conducted from three bridges and by boat on three ranges downstream from Lewiston. The location of the ranges and pertinent phenol data are shown in Figure 5. Complete mixing probably does not occur above the Whirlpool Rapids. These results show relatively high phenol concentrations on several occasions throughout the full length of the lower river.

Lake Ontario

Average and maximum phenol results for Lake Ontario in the vicinity of the outlet of Niagara River are depicted in Figure 6. Diffusion of phenol progresses from point O along the fan-like ranges, diluting out in approximately 10 mi. of travel. A maximum result of 85 p.p.b. was reported on range ON 3 mi. from point O. With the exception of 5 other results in the order of 12 to 25 p.p.b., all the maximum values were less than

8 p.p.b. and more than one-half of the maximum values were less than 3 p.p.b.

Municipal Water Supplies

There are six public water supplies on the United States side taken from the Upper Niagara River and the east end of Lake Erie. Routine sampling and analysis of the raw waters at these purification plants were integrated with river and industrial effluent studies. The operating records of the larger water treatment plants were also reviewed. These studies showed the local conditions at each water plant, as well as the progressive changes in water quality along the Niagara River.

Intakes for these water plants are shown on Figures 3, 4, and 5. Since the 1949 I.J.C. studies, the intake for Niagara Falls filter plant No. 1 has been extended from the east channel of Niagara River to the west (Emerald) channel. This new intake was placed in service late in 1951. Niagara Falls filter plant No. 2 was taken out of service in 1953, thus eliminating the only shore intake. In 1954 the town of Tonawanda was constructing a new filter plant with a tunnel intake of 140-m.g.d. capacity to be located in the west channel.

The three remaining municipal intakes located in the east channel, in the Tonawanda area, are in a precarious position with respect to the normal pollution zone. The intake for the Erie County Water Authority filter plant in Lake Erie is likewise within a mile of shore pollution and the dredge dump. During and following storms, these pollution zones widen and the intakes are thus subjected to sporadic "slugs" of heavy pollution. The town of Niagara, Ont., water supply, taken from the lower Niagara River near its mouth, is markedly affected by the phenol pollution.

Phenol concentrations as high as 80 p.p.b. were observed in the Tonawanda raw water in 1949. Concentrations of this order frequently occurred at the Niagara Falls filter plant No. 2 (shore intake) when this plant was being operated. Operation of the Erie County Water Authority plant is seriously affected by intermittent high concentrations of both phenol and iron.

The intake for the city of Buffalo is located at the Niagara River inlet near the International Boundary where the raw water is not usually affected by sewage or industrial waste pollution. Plant records for 1949 indicated that the quality of raw water taken from the Buffalo intake met the U. S. Public Health Service bacteriological requirements for a treated water. However, this plant also receives an occasional "slug" of phenol. Routine sampling picked up phenol concentrations of 45 p.p.b. on March 29 and 25 p.p.b. on April 26, 1949. These incidents both followed sustained high (35 to 40 m.p.h.) southwest winds.

The wide and rather rapid changes in the character and intensity of polluting substances in the raw water have adversely influenced treatment and purification. A sudden increase in pollution of the raw water results in a similarly sudden increase in the chlorine required for disinfection. The erratic chlorine demands experienced at these water purification plants are a continual hazard to public health. For these reasons, the New York State Department of Health has recommended that new municipal intakes in the upper Niagara River be located in the west channel.

In addition to disinfection, taste and odor control has been a major problem in the treatment of these waters for domestic use during the past 25 years. Little success was realized in this control until the introduction in 1943 of chlorine dioxide treatment. Chlorine dioxide is now used at each of the United States water plants, with the exception of Buffalo, at considerable additional expense. While this has

improved the quality of the treated water under most conditions, occasional complaints are still received.

The City of Tonawanda water purification plant operation records were examined for reported taste in the chlorinated raw water. These records showed objectionable taste occurring intermittently from the latter part of November to the middle of April, varying from year to year. Taste consistently developed following high winds, or high discharge from Buffalo River, but usually from a combination of the two. Since August 1947, the lowest Buffalo River discharge associated with taste in the water at Tonawanda was 1,380 c.f.s. during the period December 22–24, 1951, when the average wind velocity was 15 m.p.h. It appears that a substantial flow from Buffalo River is needed to cause sufficient lateral dispersion and to offset dilution in Niagara River to affect the Tonawanda public water supply.

Industrial Water Treatment

Phenol has been reported to be a problem where a high quality process water is required. This is particularly true in manufacture of products which come in contact with food. Caustic wastes have raised the pH of the receiving waters sufficiently to interfere with coagulation of water taken from nearby shore intakes.

Fish and Wildfowl

Some 20 fish kills have been reported in the Buffalo-Tonawanda-Niagara Falls area during the past 17 years. Three of these kills occurred during November and December 1937 in the Buffalo Harbor area and were reported by the Buffalo Sewer Authority. The remaining fish kills have occurred since 1943, the last major destruction of fish being during the third week of March 1953. Most of the fish kills have been investigated and reported by the New York State Department of conservation.

While the relative severity of each of the kills has not been estimated, the causative toxic agent for most of them has been determined. Cyanides were implicated as causing nine of the kills, with phenols a contributing factor in two cases. A lethal dose of chlorine presumably was the cause of two of the kills, while high concentrations of copper and iron salts possibly caused four others. The toxic materials causing the remaining kills, which include the three in 1937, could not be isolated. A large portion of the fish destroyed has been minnows, particularly the "lake shiner." However, pike, bass, sunfish, and crayfish have been killed in lesser numbers. The sources of the polluting substances causing these kills have been identified in several instances.

Destruction of fish is an obvious manifestation of damage from pollutional materials. There are other more subtle effects on both the fish and the food on which they must feed. Settleable solids tend to blanket the bottom of these boundary waters. Such materials as tar- and oil-coated solids are toxic to aquatic organisms. The detrimental effect of numerous soluble materials although recognized, is difficult to accurately express. Cognizance has been taken of natural conditions which may influence fish life.

Because the Niagara River is an important gathering point for migratory wildfowl, any pollution causing damage to the fowl is of economic importance. Oil coating of protecting plumages not only causes over-exposure in icy waters, but also renders the birds helpless. Occasions have been reported of large numbers of birds being swept over the falls as a direct result of oil pollution.

Navigation

A considerable portion of the suspended solids previously described settles readily. Those solids discharged directly to the boundary wa-

ters and navigable tributaries, together with silt from natural erosion, require a routine dredging program. In some instances the source of the solids of industrial origin can be identified.

Recreation

The waters in the Buffalo area and in the lower Niagara River below Lewiston and Queenston are widely used for pleasure boating. Some 1,800 small power boats use the waters in the eastern end of Lake Erie and the Upper Niagara River. Serious damage to boat hulls from oil was reported by the owner and operator of one marine supplies establishment.

Pollution has interfered with development of areas suitable for bathing. Swimming along the waterfront of residential property is practiced with little regard for the health hazards. The State-operated bathing beach at the south end of Grand Island is satisfactory, but remotely located with respect to the center of population.

Progress in Pollution Control

Reduction in quantities of pollutional materials discharged to the boundary waters during the period 1949–54 is shown by comparison in Tables II and III. The methods of accomplishing these reductions have been briefly described in the sections dealing with the particular wastes. The greatest reductions have been in cyanides and suspended solids. The slight increase in oil waste is temporary as explained in that section. Real progress has been made in providing facilities to prevent oil losses. In numerous instances, modernization and process changes have reduced wastes. In others, recovery has proven a profitable venture. During this same period, industry expanded and production was generally on a higher level in 1953 than it was in 1949.

New facilities currently being installed at a number of plants will further reduce waste losses. Many of the industries are solving their waste problems simultaneously with the design of new equipment. Others are actively engaged in research in an effort to develop suitable control and treatment processes.

Continuing Program

There is evidence of a definite trend toward monitoring of industrial effluents with the view of establishing a continuous and permanent record. This is an essential requirement in the development of an equitable pollution abatement program for a highly industrialized area such as the Niagara Frontier. The substantial progress that has been achieved by industry and the planning for the future are consistent with the doctrine of "best usage of waters in the public interest" promulgated by the New York State Water Pollution Control Board.

References

1. "Report of the International Joint Commission, United States and Canada, on the Pollution of Boundary Waters" (1951).
2. Symons, G. E., Fynn, G. F., and Brown, H., "Industrial Waste Pollution Abatement Program for Buffalo, N. Y." *Sewage Works Jour.*, **20**, 5, 861 (Sept., 1948).
3. New York State Water Pollution Control Board, "Lake Erie (East End)—Niagara River Drainage Basins." Report No. 3 (May, 1953).
4. New York State Department of Health Water Pollution Control Board, "Rules and Classifications and Standards of Quality and Purity for Waters of New York State" (Oct. 25, 1950).
5. Symons, G. E., and Crane, F. W., "Special Sewer Service Charges for Industrial Wastes." *Water Works & Sewerage*, **91**, 3, 113 (1944).
6. Smith, E. J., "Effects of Chemical Industry Wastes—Niagara Falls, N. Y., Sewage Treatment Plant." THIS JOURNAL, **23**, 12, 1567 (Dec., 1951).

7. Black, H. H., and Oeming, L. F., "Survey of Industrial Wastes in the Lake Huron-Lake Erie Section of the International Boundary Waters—Part 2." THIS JOURNAL, **23**, 4, 517 (Apr., 1951).
8. Kirchgessner, N. H., "Treatment of Phenolic Plastics Wastes." THIS JOURNAL, **22**, 10, 1314 (Oct., 1950).
9. Fell, G. E., "The Currents at the Easterly End of Lake Erie and Head of Niagara River." *Jour. Amer. Medical Assn.*, **55**, 828 (1910).

DISCUSSION

By Lyman Cox

Manufacturing Superintendent, E. I. du Pont de Nemours & Company, Buffalo, N. Y.

Few people have any conception of how unusual the Niagara River really is. Under the heading "Hydrographic Information" the authors refer to a minimum mean monthly flow of 117,000 c.f.s. This is truly an enormous flow when one remembers that many inland streams regarded as large rivers have minimum flows in the order of 1,500 to 2,500 c.f.s. The Niagara is also unusual in its clarity; the water is cold for a river. Floods are of little consequence as compared to most rivers. On the other hand, the Niagara is more severely affected by wind velocity and direction and by the formation of ice.

In addition, people generally have a misconception concerning the extent to which the Niagara River is polluted. This is understandable because the river, being very important to the cities and industries along its banks, has received a lot of attention, mostly stressing the need for improving water quality, possibly to the point where many have the idea that the Niagara is a grossly polluted river. This is far from being the case. Actually, the water of the river is of excellent quality for most purposes, causing concern only as pollution proves troublesome to municipal water supply. In fact, the area around Strawberry Island, below several possible sources of major pollution, is considered the finest bass fishing location in the whole region.

Mention also is made of the New York State Water Pollution Control Law and the plans under way for classifying the river. The writer has been surprised at the amount of newspaper publicity on this subject and the references made to the undesirability of the "C Special" classification proposed by the Board. The clamor for putting the East Branch of the river in classification "A" probably stems from lack of knowledge concerning the standards and what they are designed to accomplish. It possibly also stems from the fact that few people recognize the effect that storm overflows from the Buffalo sewer system have on the East Branch of the river and the impracticality, if not impossibility, of correcting this source of pollution.

Research Activities

PUBLIC HEALTH SERVICE RESEARCH GRANTS IN ENVIRONMENTAL HEALTH

By Irving Gerring

Executive Secretary, Public Health and Sanitation Study Section, Division of Research Grants, National Institutes of Health, USPHS

The research grants program of the U. S. Public Health Service is one of several Government-sponsored research programs financed through Congressional appropriations. The National Institutes of Health research bureau of the Public Health Service, is responsible for the major portion of the medical research sponsored by the Federal Government. The Service's appropriation for research grants has gradually increased from less than $1,000,000 in 1946 to more than $28,000,000 in 1954.

The Public Health Service Act (Public Law 410, 78th Congress) provides that the Surgeon General shall "encourage, cooperate with, and render assistance to appropriate public authorities, scientific institutions and scientists in the conduct of, and promote the coordination of research, investigations, experiments, demonstrations, and studies relating to the causes, diagnosis, treatment, control, and prevention of the physical and mental diseases and impairments of man, including studies of water purification, sewage treatment, and the pollution of lakes and streams."

Research Grant Mechanism

The Public Health Service Act also provides that the Surgeon General may "make grants in aid to universities, hospitals, laboratories, and other public or private institutions, and to individuals for such research projects as are recommended by the National Advisory Councils." Members of the councils are nongovernment workers in science, education, and public affairs. To assist the advisory councils on highly technical matters, study sections of experts in 17 special fields have been appointed. These study sections have two major responsibilities: (a) to review applications for research grants and provide technical advice on action to be taken, and (b) to survey the total research being conducted in the section's field, in order to stimulate additional work in neglected areas. Hence, the councils and study sections are responsible for a major portion of the guidance and administration of the Public Health Service research grants program. Applications for research grants in the field of environmental health are first reviewed by the Public Health and Sanitation Study Section, and final recommendation is made to the Surgeon General by the national advisory council concerned.

Although research grants may be made to individuals, they are usually made to an institution. Individuals find it advantageous to affiliate with universities or institutions because this facilitates the administration of a grant, provides the research worker with better facilities, and promotes collaboration with colleagues.

The aim of the Public Health Service is to promote the highest quality

of endeavors in both fundamental and applied research, without restrictive regulations. Complete scientific freedom is accorded the investigator. Although applications for grants are evaluated primarily on the basis of scientific merit of the proposal, the scientist is free to modify his research design as the study progresses, and to publish his results as he sees fit.

Types of Projects Eligible for Support

Research projects related to sewage and industrial wastes are eligible for support so long as they bear directly or indirectly upon problems of health or disease. Projects exclusively or predominantly of local importance and those which merely demonstrate the application of accepted scientific techniques are usually not recommended for support.

It is important to note that the very title "Research Grant" connotes a distinction between projects that are only demonstration or control measures and those that are research. It is realized that many projects in environmental health are a combination of demonstration, control, and research activities. In such cases, the Study Section must make the determination, sometimes difficult, as to where the true emphasis lies. Research constitutes experiment or theoretical analysis leading to increased knowledge of natural phenomena, or it may be a collection of information needed prior to research projects for their proper conduct. In the field of environmental health, research may include the application of any basic data toward the devising of a new technique or piece of equipment, or it may be merely the testing of such techniques or equipment for the purpose of determining clinical or experimental uses.

A project may satisfy these definitions of research and still not merit support. Superior and inferior applications are received, and each must be subjected to such tests as the following:

1. Is the investigator competent to do the work proposed?
2. Is the problem significant to medical or closely allied research?
3. Will the applicant have the necessary facilities to do the work?
4. Does the project director have so many other responsibilities that he cannot give the necessary time to the research?
5. Is the requested budget reasonable in relation to the work proposed?
6. Is the proposal clearly defined and planned, with comprehension of previous work related to the problem?
7. Is necessary collaboration from fellow scientists or other agencies definitely assured?

Public Health Service Policy Considerations

Every effort is made to ensure that Public Health Service research grants do not disrupt the normal operation of the institution. In this connection, the Public Health Service has adopted certain policy designed to preclude this danger, as follows:

1. Each grant must be approved by the dean or other administrative officer in charge, on the assumption that he will assume responsibility for keeping salaries in line with others at the institution.
2. All or part of the salary of professional personnel may be paid from research grant funds to the extent that it has previously been paid from other than regular institution funds.
3. Summer salaries may be paid only in those cases where assurance is given that the institution allows its employees to accept extra compensation for summer or vacation service, whether rendered to the institution or to others.
4. Summer compensation may, upon recommendation of the reviewing consultants, be allowed from research grant funds for two months at a rate of

one-ninth of the annual salary for each month.

5. Travel funds may be used for travel incidental to the successful prosecution of the research project, but not for foreign travel to international meetings.

6. Equipment purchased with research grant funds becomes the property of the grantee institution.

7. Grant funds may not be used to free the institution of its normal administrative responsibilities.

8. Grants are made on the principle of granting cash for one year, with moral commitment for an additional two to four years.

PHS Grant Support for Research in Sewage and Industrial Wastes

Since 1947, 42 projects have been supported in the field of sewage and industrial wastes, amounting to $880,083. This represents about 0.8 per cent of the total of approximately $120,000,000 appropriated from 1946 to 1954. Twenty-two institutions in 15 states have received support in this area.

To indicate the types of research that have been acceptable in this program, there follows a list of projects currently in progress:

Algae symbiosis in sewage oxidation ponds, Harold B. Gotaas, University of California, Berkeley, Calif.

Ecological study of estuarine polychaetous annelids, John L. Mohr, University of Southern California, Los Angeles, Calif.

Citrus waste purification, James B. Lackey, University of Florida, Gainesville, Fla.

Ecological effects of sewage in Biscayne Bay, F. G. W. Smith, University of Florida, Gainesville, Fla.

Metabolic activity of the organisms on trickling filter stones, D. E. Bloodgood, Purdue University, Lafayette, Ind.

Aerobic waste treatment processes, Ross E. McKinney, Massachusetts Institute of Technology, Cambridge, Mass.

Methods of air dispersion in the activated sludge process, Arthur T. Ippen, Massachusetts Institute of Technology, Cambridge, Mass.

Biochemistry of synthetic detergents, C. N. Sawyer, Massachusetts Institute of Technology, Cambridge, Mass.

Effect of cyanides on trickling filter process, C. Fred Gurnham and John R. Snell, Michigan State College, East Lansing, Mich.

High-rate composting of organic wastes, John R. Snell and R. F. McCauley, Michigan State College, East Lansing, Mich.

Tubercle bacilli in sewage treatment processes, H. Heukelekian, Rutgers University, New Brunswick, N. J.

Anaerobic digestion of sewage solids, H. Heukelekian, Rutgers University, New Brunswick, N. J.

Protein, carbohydrate, and fat degradation products of sewage, H. Heukelekian, Rutgers University, New Brunswick, N. J.

Effect of synthetic detergents on the activated sludge process, Gail P. Edwards, New York University, New York, N. Y.

Use of oxygen in waste treatment, Daniel A. Okun, North Carolina State College, Raleigh, N. C.

Median tolerance limit of organisms in streams, Ruth Patrick, Academy of Natural Sciences of Philadelphia, Pa.

Biochemistry of waste disposal processes, G. H. Dunstan and R. E. Hungate, University of Washington, Seattle, Wash.

In the field of environmental health as a whole, 112 research projects have been supported during the period September 1946 to March 1954. These 112 research projects may be grouped into the following categories:

Category	Number of Projects	Amount Approved
Water	27	$ 512,398
Sewage	28	616,330
Industrial waste and stream sanitation	14	263,753
Air hygiene	14	469,771
Food	11	177,105
Rodent control	3	98,010
Insect control	5	106,119
Milk and milk products	6	63,766
Swimming waters	2	6,808
Garbage disposal	2	34,500
Total	112	$2,348,560

By March 1954, 65 of these projects had been completed and 47 were in active progress.

Neglected Areas of Research

Public Health Service consultants who are members of the Public Health and Sanitation Study Section are unanimous in their advice that much additional research should be initiated in the field of sewage and industrial wastes, as well as in the broad field of environmental health. It is their consensus that the following problems need further development:

Sewage and Industrial Wastes—More economic methods and improved scientific techniques for biological, chemical, and physical analyses of water, sewage, and industrial wastes, in order to ensure safe drinking water supplies and to prevent stream pollution.

Environmental Health—Pasteurization processes of milk and milk products; studies on pathogens in relation to frozen foods and other food products; problems of atmospheric pollution in relation to radioactive material; studies pertaining to bacterial, chemical, and physical aspects of air pollution for the control of virus infections and toxic substances; studies on the biology of poisons and insecticides as related to rodent and insect control; hygiene in housing; accident prevention.

Method of Applying for Research Grants

Requests for support are submitted by the institution on behalf of the investigator's proposed research, using special application forms which may be obtained from the Division of Research Grants, National Institutes of Health, Bethesda 14, Md. The Division is responsible for the fiscal and technical processing of all research grants awarded by the National Institutes of Health, and is fully responsible for administering the grants in study areas not encompassed by the program of any institute. (These "categorical" institutes correspond to the national advisory councils.) Applications received between November 1 and March 1 will be reviewed by the various advisory councils in June, those received between March 1 and July 1 will be reviewed in October, and those received between July 1 and November 1 will be reviewed in February.

THE OPERATOR'S CORNER

CONDUCTED BY HERBERT P. ORLAND

SCREENINGS AND GRIT COMPLICATE STARTING OPERATIONS AT NUT ISLAND SEWAGE TREATMENT PLANT *

BY JOSEPH B. HANLON

Superintendent, Sewage Treatment Plants, Metropolitan District Commission, Boston, Mass.

The Nut Island sewage treatment plant of the Metropolitan District Commission was put into continuous operation on May 6, 1952. Prior to that date certain units, including the bar screens, the chlorinators, the outfall diffusers, and one generating engine, were used for various periods, primarily to expedite construction of the new plant and to maintain the long-established practice of screening raw sewage before discharge.

Located on the inner harbor at the terminus of the South Metropolitan Sewerage District in Quincy, Mass., a thickly populated residential and recreational area, the plant was constructed at a cost of about $10,000,000. Designed for primary treatment of 112 m.g.d. average to 300 m.g.d. maximum, features include pre- and post-chlorination, primary and secondary sludge digestion, pre-aeration of influent, and power generation by dual-fuel engines. Figure 1 is a flow diagram of the plant; general design data have been given in a previous paper (1).

Examination of the operating results obtained between May 6, 1952 and March 31, 1954 confirms the fact that one-third of the Boston Harbor pollution problem is solved. This is further evidenced by the general improvement in the area, the absence of scum and floating solids which formerly surrounded the outfalls, the reduction of bacterial pollution during the recreational season as indicated by sanitary surveys, and more recently by the reopening of large shellfish areas. Table I is a summary of 1953 operating data.

Purchase and Storage of Equipment

Construction work began in October 1945, with purchase and delivery of all principal equipment occurring during 1946 and 1947. The project was plagued, however, by long delays due to lack of appropriations and other reasons, which meant the equipment had to be stored in temporary shelters. The operating difficulties and maintenance problems resulting from this lengthy storage have been many.

Operating Force

Of equal importance to both functions has been the difficulty of interesting and obtaining capable help. This problem had to be solved by training sufficient personnel while battling the operation and maintenance problems associated with the starting of a new plant.

The total force allowed, clerical and laboratory help included, was 59 employees. Five operating crews were

* Presented at 25th Annual Meeting, New England Sewage and Industrial Wastes Assn.; Boston, Mass.; April 22–23, 1954.

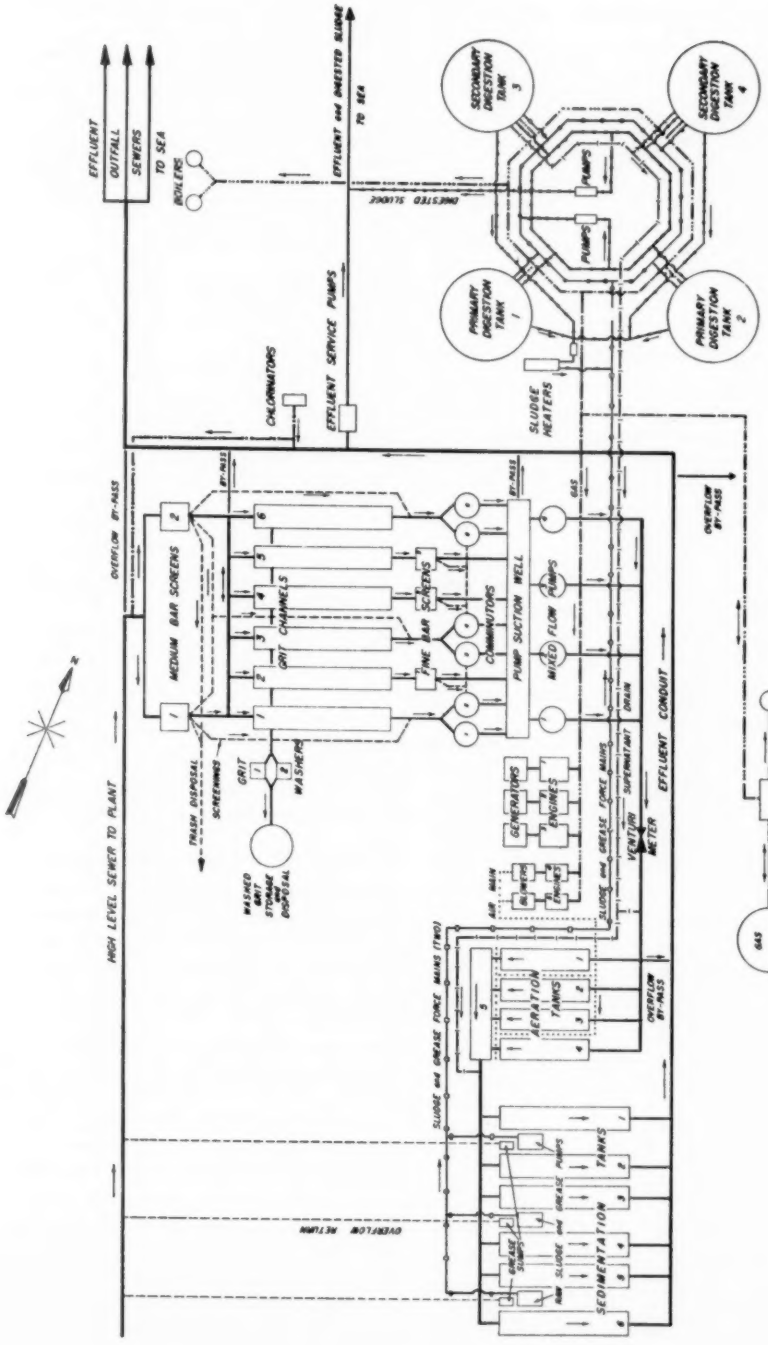


FIGURE 1.—Flow diagram of Nut Island sewage treatment plant.

TABLE I.—Summary of 1953 Operating Data for the Nut Island Sewage Treatment Plant

Item	Average
Sewage flow (m.g.d.)	111.3
Grit removed (cu. ft./m.g.)	0.5
Vol., as collected (%)	24.1
Vol., washed grit (%)	8.3
Total susp. solids (p.p.m.):	
Influent	146.9
Effluent	71.4
Removal (%)	51.4
Removal (lb./day)	70,125
Settl. solids (ml./l.):	
Influent	3.8
Effluent	0.3
Removal (%)	92.1
B.O.D., 5-day (p.p.m.):	
Influent	121.3
Effluent	78.0
Removal (%)	35.7
Removal (lb./day)	40,217
Chlorine demand (p.p.m.):	
Influent	4.2
Effluent	3.2
Chlorine residual, effl. (p.p.m.)	0.16
Bacteria (MPN/100 ml.): *	
Influent	39.1×10^6
Effluent	14.6×10^3
Kill (%)	99.96
Grease-scum † (p.p.m.):	
Influent	67.5
Effluent	37.9
Removal (%)	43.9
Removal (lb./day)	27,492
Raw sludge:	
Solid content (%)	5.06
Added to prim.‡ (m.g.)	78.795
Added to prim.‡ (dry tons)	17,085
Vol. content:	
(%)	77.9
(dry tons) ‡	13,310
pH	6.17
Alkalinity (p.p.m.)	371.0
Digested sludge:	
Solid content (%)	9.94
Removed from secondaries:	
(m.g.) ‡	13.370
(dry tons) ‡	5,545
Volatile content, dry (%)	50.0
Reduction, total sol. (%)	54.2
Reduction, vol. sol. (%)	69.6
Digester gas:§	
Produced (m. cu. ft.)	224.93
Produced (cu. ft./lb. dry sol.)	8.20
(cu. ft./lb. vol. sol.)	10.72
(cu. ft./lb. sol. destr.)	15.23
CH_4 (%)	62.9
CO_2 (%)	34.7
H_2S (gr./100 cu. ft.)	5 to 15

* Recreational season.
† Petroleum ether soluble.
‡ Total for year.
§ From April 23, 1953; does not include amount vented.

allowed to cover the 21 shifts per week required under Massachusetts' 40-hr. work week. Each crew is comprised of one treatment plant operator, two attendants, one diesel operator, one skilled and one unskilled laborer, with the fifth crew required to cover operating duties one day each week and be available for maintenance work the remaining four days.

In practice this arrangement has not been satisfactory. The amount of maintenance work has been much greater than anticipated; the maintenance force has had to be depleted frequently to give priority to operating duties; and the practice of equal monthly shift rotation for these five crews has seriously interfered with the carrying out of an efficient maintenance program. In short, it is hoped that when the vacancies in the fifth crew are filled maintenance can be separated from operation entirely.

Mechanically-Cleaned Bar Screens

Raw sewage entering the plant originally passed through mechanically-cleaned inclined bar screens having 9/16-in. diameter round rods, spaced 2 1/16 in. on centers. After five months use it was apparent that the screen rakes were of insufficient strength. Further, the spacing of the bars was such as to allow the passage of material, principally rags, that should be removed.

All rakes were removed for straightening and strengthening by the addition of Z-bars. Replacement of the bars with a much heavier rod, and consequent reduction of the free openings, was approached with caution, as the amount of screenings intercepted

at times was great and it was felt that reduced openings might result in shutting off the flow at periods of heavy loads. However, failures experienced with equipment after the plant went into full operation made the screen conversion mandatory. New 7/8-in. diameter rods were installed. This reduced the free openings from 1½ to 1¼ in., and eliminated the flexing and spreading which were present with the original rods. The rakes were removed and the slots milled to fit the new rods.

During normal flow the screens are controlled by automatic time clocks, with operating cycles limited to avoid unnecessary wear. Both units are used at all times in order to maintain reasonable velocities through the screens.

Grit Channels

Six grit channels of conventional design were constructed to provide velocities of approximately 1 ft. per second. Enclosed throughout, the channels are 80 ft. long, 10.5 ft. wide, and of 40-m.g. capacity each.

Up to April 1954, 178 grit channel failures had been recorded. However, only 11 of these occurred during the last six months, which in itself reflects the amount of maintenance work that went into these units.

Failures were due in many instances to large solids and rags which reached the grit channels after passing through the main screens and formed bundles of sufficient size to jam the buckets or lift the chains off their sprockets. Alterations to the main screens reduced this type of failure considerably.

Other causes of mechanical failures were experienced and corrected as follows:

1. The use of a cotter key type of pin for holding the grit buckets to the bucket holders caused frequent failures when the pins dropped out. By drilling each bucket holder and installing a straight length of ½-in. round rod, secured in place by inserting the wearing shoe on top of it, the original pins and the failures were eliminated.

2. Other failures were caused by grit buckets hanging up on rail clips as slight wear on the wearing shoes decreased the clearance between buckets and clips permitted the buckets to drop sufficiently to come in contact with the clips. Replacement wearing shoes providing a wider bearing surface were used and holding clips interfering with the travel of buckets as normal wear occurred were burned off flush with the concrete floor.

3. Fresh-water lubrication lines for submerged bearings which were pulled off their supports by the weight of solids adhering to them were not replaced.

4. Failures, when cutting in channels, from accumulations of grit entering the channel and burying the mechanism were eliminated by placing the equipment in motion first, with inlet and outlet gates partially open, thereby removing grit accumulations gradually.

Collecting mechanisms in channels being used are operated 20 min. every 4 hr. Mechanisms in channels out of service are rotated once each 8-hr. watch.

Grit Washing and Handling

Grit washing and handling were impossible for a lengthy period after operations began due to the quantity of rags, sticks, cans, wire, and other miscellaneous material which entered the washers. Floats were inoperative and washer beds became clogged, as did the pumps provided to handle the washer discharge and the accumulation of grit which resulted from frequent dewatering of the grit channels. The problem persisted despite the installation of screens at the washers, effluent lines for additional flushing and wash water, compressed air lines for agitation of solids and accumulated

grit, and later the installation of a pre-breaker to grind solids before pumping. Conversion of the main screens helped with these problems, as did the present system of plowing all grit collected back into the flow for pre-washing in the channel located adjacent to the grit washers.

Quantities of grit collected have varied over wide ranges, depending on flows and weather conditions. For three months in 1954, grit removal averaged 36.4 cu. ft. daily unwashed and 9.2 cu. ft. daily washed.

The advisability of washing grit at the main floor level, which would eliminate the difficult job of pumping the material discharged from the washers and the operation and maintenance of elevating equipment, has been considered.

Comminutors and Fine Bar Screens

Three of the six grit channels are followed by 36-in. comminutors, the other three by fine bar screens having ½-in. clear openings. During normal flows of about 120 m.g.d. the three grit channels followed by comminutors are used at all times. When flows exceed 120 m.g.d., one or more of the channels equipped with fine bar screens are used and the screenings sluiced to one of the comminutor wells for grinding.

Comminutor operating difficulties have developed when the amount of rags and stringy material reaching them has exceeded their capacity. On occasion, as much as 30 cu. ft. of this material has been removed manually from the comminutor pits. On other occasions the rags have shut off the flow through the comminutor drums, causing the sewage to pass over the overflow. It is expected that when an incinerator, now under consideration, is provided and all coarse screenings collected at the main screens are disposed of by incineration this difficulty will be eliminated. Samples of grit-impregnated rags removed at the comminutors were analyzed for determining the percentage of grit present and its effect on cutting teeth life. Results as high as 27.6 per cent dry weight were obtained.

Magnetic Drive of Main Sewage Pumps

The first application of the magnetic drive to provide variable-speed control for vertical sewage pumps was installed at this plant. Each of the four pumping units (Figure 2) consists of a 200-h.p., 2,300-v., vertical synchronous motor direct-connected to the ring section of a magnetic drive, which forms the driving component. A magnet, or driven element, separated from this ring by a ¼-in. air gap is keyed to the input shaft of a vertical planetary reduction gear, with the output shaft of this gear direct-connected to a 48-in. 83-m.g.d., mixed-flow, raw sewage pump.

The units have been operated as needed to handle wide variations in flows and have performed satisfactorily, in particular on automatic control, in maintaining the elevation of the wet well within prescribed limits. Because the average daily flow exceeds the capacity of one unit, except for a very limited period during midsummer, not less than two units are on continuous duty with the load divided between them. The third and fourth units take care of peaks.

As expected, some minor changes were made in the control potentiometers, the tachometer generator drives, and reduction gear oil seal retainers. Replacement of original thrust bearings was necessary due to the effects of storage.

The maintenance schedule on these units is to remove one unit quarterly for complete disassembly, thorough cleaning, application of insulating varnish to windings, inspection and lubrication of thrust bearings, turning down of exciter commutators and magnetic drive slip rings, with renewal

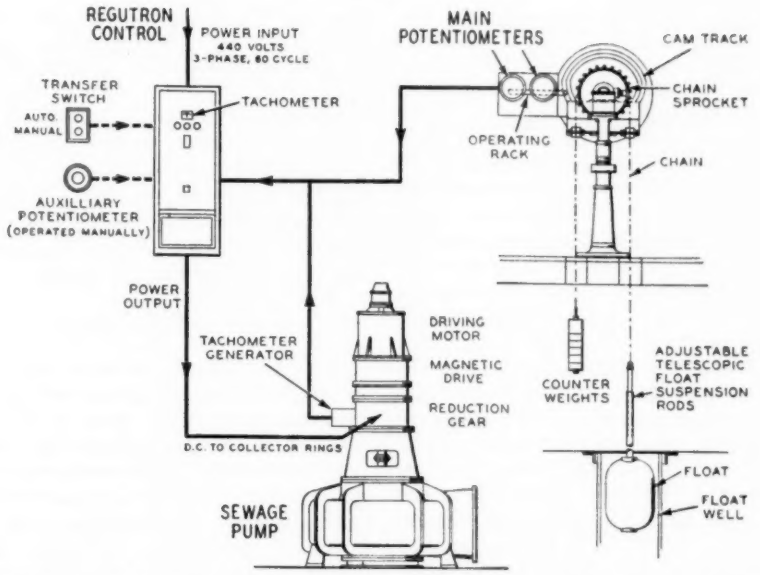


FIGURE 2.—Float control assembly and connections to magnetic drive of main sewage pump. (Drawing courtesy of Electric Machinery Mfg. Co.)

of brushes as needed. Maintenance of the Regutron controllers has been limited to periodic checks and replacement of amplifier and power tubes, and voltage checks between panels and terminals, with adjustment as needed.

Engine Room

One spark-ignition straight gas and two dual-fuel engines, driving 575-kw., 2,300-v. alternators, have produced a total of 8,291,460 kw.-hr., meeting all plant demands for electrical power. Two engine-driven blower units of 5,000-c.f.m. capacity each, supplying air for pre-aeration, have operated a total of 23,457 hr. Operation on gas fuel is routine, with 15-min. switchovers to oil operation, required for purging fuel injectors, once every 8 hr.

The frequency of servicing this equipment is determined by the maximum number of operating hours obtainable consistent with safety and economy. Bearing inspections are made at 2,000-hr. intervals; pistons, rings, and wrist pins at 8,000 hr.; intake, exhaust, air-starting, and gas valves at 4,000 hr.; fuel injection and ignition equipment at 1,000 hr. Fuel, water, and lubricating oil analyses are run at regular intervals.

Projects underway or contemplated include installation of additional intake and exhaust silencing equipment to provide further reduction in exterior noise levels, installation of six exhaust fans to maintain reasonable engine room temperatures by improving ventilation, and a means for reducing interior noise levels, especially from gear boxes, to within reasonable working limits.

Venturi Meters

A 120- by 60-in. venturi meter located between the main pumps and the pre-aeration tanks provides flow measurement of the plant influent and automatically proportions chlorine dosage. Two 6-in. by 3-in. venturi meters measure raw sludge pumped to digesters.

Maintenance is by plant personnel and consists principally of weekly

purging and calibration, with degreasing of sludge venturi throats by use of live steam.

Pre-Aeration Tanks

The five pre-aeration tanks are equipped with swing diffusers mounting a total of 1,628 porous tubes. Four tanks are arranged in parallel; a fifth tank, 85 ft. in length, is extended across the outlet end to form a section of the sedimentation tank influent conduit.

After seven months use it was observed that the air diffusers were not operating properly. The tanks were dewatered in pairs, starting with No. 4, which had evidenced the worst condition. A total accumulation of about 50 cu. ft. of grit and rags was discovered to be the cause of the trouble. Quantities of the rags showed evidence of having passed through the comminutors and, due to turbulence in the tank, were securely caught on the diffuser tubes (Figure 3). All tubes were cleaned or replaced with spares; the tanks were cleaned and returned to service.

Because 10 months elapsed before conversion of the main screens was completed, a second inspection and cleaning has become necessary. Replacement with saran-wrapped tubes is being made in tank lots as the need requires.

The second inspection has indicated the need of a device or method for frequent use by plant operators that will register the velocity in the grit channels, especially when the flow is split between channels having comminutors and those having fine bar screens.

Sedimentation Tanks

Operation of sedimentation tank collection equipment is alternated on 1-hr. intervals between tanks 1, 3, and 5, and 2, 4, and 6. During off periods, cross collectors in the pump suction pits are operated to move the material into position for pumping. Early operating experience indicated that longer shutdown intervals were undesirable if the sludge was to be collected in a fresh condition.

After approximately 12 months' use, each tank was taken out of service for cleaning and repairs, including resetting of all weir plates to their proper elevation. From this inspection it was apparent that this maintenance work should be scheduled at 10- to 12-month intervals.

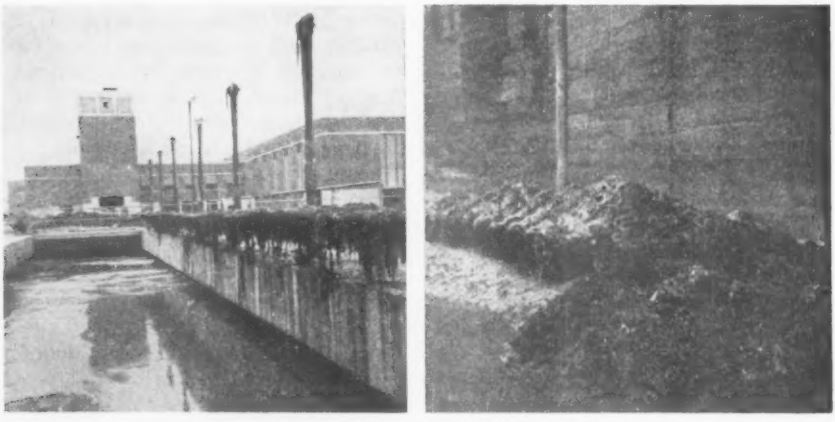


FIGURE 3.—Accumulations of rags on diffusers in pre-aeration tanks prior to screen and grit chamber changes.

Raw Sludge

The amount of raw sludge collected each 24 hr. at the sedimentation tanks is 272,000 gal., in addition to about 3,000 gal. of scum and grease. Transferring this combined load to the digesters by pumping through some 2,400 ft. of 6-in. diameter pipe is responsible for the most difficult operating and maintenance problem encountered. The lines, which were designed to provide free passage for a flexible pipe cleaner, are buried well below grade and have few cleanouts or vents. With these lines out of service, sludge transfer is stopped, followed by a rapid build-up of sludge in the sedimentation tanks. The collectors become overloaded and in hot weather the tank contents become septic, causing the acid sludge to gasify, become buoyant, and thereby resist collection, while the odor problem becomes serious.

In starting up, the services of every available man were required to keep these lines open. The pipe cleaner was used in every possible manner without success. Hard solid plugs formed ahead of the cleaner by the material being removed; on occasions these plugs measured 30 to 70 ft. long. Excessive pump discharge pressures resulted, with some damage to plunger pumps; scrupeller pumps were inoperative because shutoff heads were reached.

These difficulties continued until the present system of circulating hot liquid at high velocity through the lines and fittings was worked out. Additional alterations are needed to perfect this simple method of maintaining normal line pressures; however, only one stoppage has occurred in the seven months since use of the pipe cleaner was abandoned. Recommendations for collecting daily scum and grease loadings at each grease pit for disposal by incineration are under consideration.

Digesters

The four digesters are of 110-ft. diameter, 32-ft. sidewall depth, with a working capacity of 2.3 m.g. each. Primary tanks No. 1 and 2 have fixed roofs and are paired for operation with secondary tanks No. 3 and 4, which have floating covers. Normal elevations in the tanks, also make-up and overflow requirements, are maintained by a weir box arrangement which houses telescopic valves, weir, and float-operated effluent supply inlet (Figures 4, 5, and 6).

While starting other sections of the plant, the raw sludge collected at the sedimentation tanks in amounts of approximately 250,000 g.p.d. had to be disposed of through a 12-in. diameter harbor line designed and installed to handle digested sludge only. On July 14, 1952, this line became plugged, with the result that the well-planned procedure for starting the digesters had to be abandoned, with the daily accumulation of raw sludge pumped to the No. 1 primary for storage. When the line was cleared, some days later, it was decided not to unload this quantity of acid sludge at the height of the recreational season, but rather to attempt starting of the digesters. Both primaries were filled with plant effluent, tank vents were closed, and heating by recirculation of the contents through heat exchangers to obtain a temperature of 90° F. was begun. Sufficient effluent mixture was also added to the secondaries to float the covers and otherwise place them in proper relationship to their respective primaries.

In filling the No. 2 primary a combination of effluent and raw sludge was obtained which yielded a mixture of about 1 per cent solid content. Close laboratory control was maintained on both primaries from this point on, with tank analyses for the next 90 days showing a pH of 5.0, alkalinity of 1,500 to 2,000 p.p.m.,

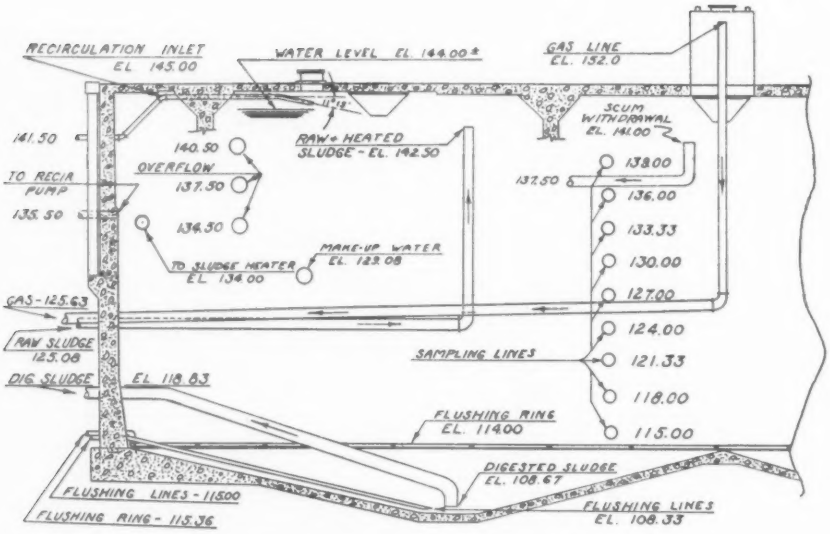


FIGURE 4.—Primary digester piping, Nut Island plant.

volatile acids of 4,000 pp.m., and a "dry weight solid content of 1/40th of the tank's volume."

By August 21, 1952, related plant operating conditions were such that daily raw sludge additions of 20,000 gal. to each primary were possible, with overflow going to the No. 3 secondary. On September 1, 1952, the first gas sample obtained at No. 2 primary showed 30 per cent methane and 40 per cent carbon dioxide. On September 10, the first gas sample obtained from No. 1 primary tank

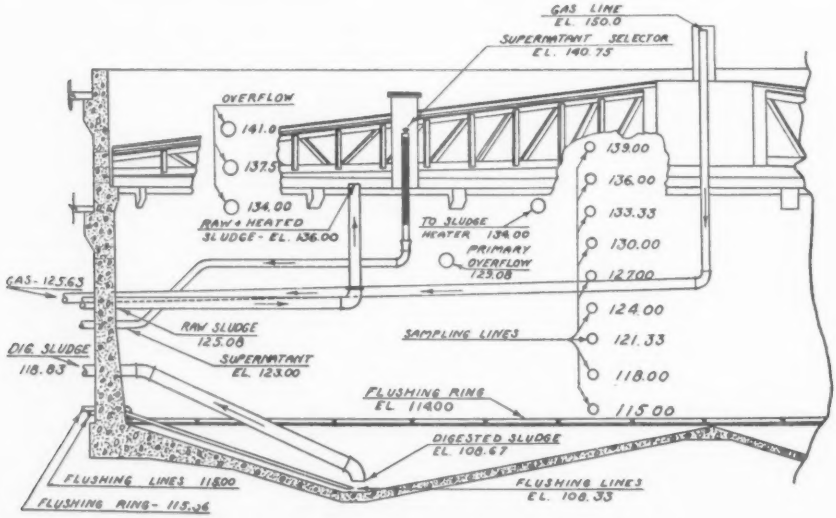


FIGURE 5.—Secondary digester piping, Nut Island plant.

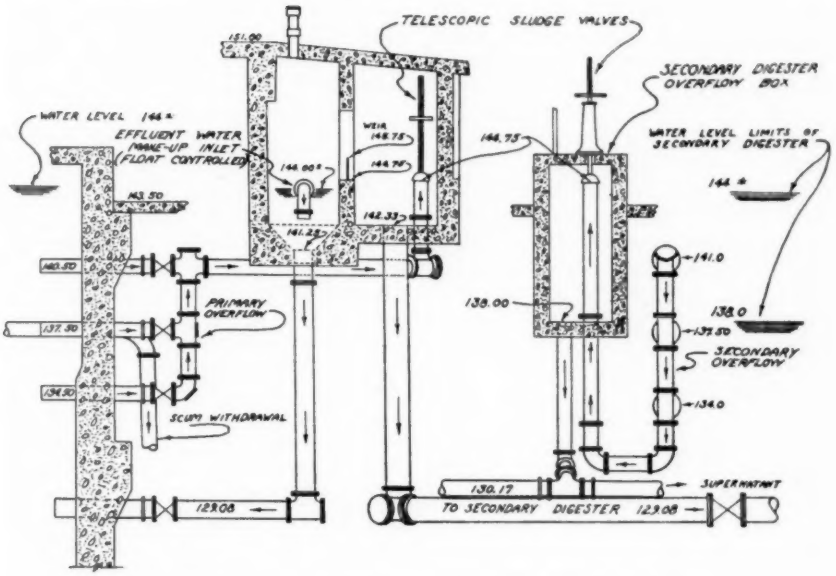


FIGURE 6.—Digester overflow arrangement, Nut Island plant.

registered 25 per cent methane and 55 per cent carbon dioxide. Thorough mixing, recirculation, and heating were continued, with raw sludge additions governed by the amount of carbon dioxide indicated from the daily gas analysis. On October 17, when no significant improvement was apparent in gas quality or analyses of tank contents, it was decided to lime the tanks. The grease hoppers at the sedimentation tanks were ideally located for this purpose. A lime slurry was mixed and then bled into the digesters with the daily raw sludge feedings. During the next 13 days 13,000 lb. of lime were added to the No. 2 digester and a gas analysis of 45 per cent carbon dioxide and 45 per cent methane noted. An additional 7,000 lb. of lime were added over the next 25 days, with tank contents now registering a pH of 6.2, alkalinity of 2,000 p.p.m., and gas content of 35 per cent carbon dioxide and 60 per cent methane. During the next 30 days an additional 2,000 lb. of lime were added, with continued improvement of pH, alkalinity, and gas quality recorded until on January 9, some five months after starting, this tank showed a constant pH of 7.0, alkalinity of 2,400 p.p.m., volatile acids of 300 p.p.m., and gas analysis of 29 per cent carbon dioxide and 66 per cent methane. The total amount of lime added to the No. 2 primary digester was 22,000 lb.

Up to November 15, little attention was given the secondaries, as the primaries were the principal concern. However, No. 3 secondary had been receiving the bulk of primary overflow and on this date strong gasification was noted. Laboratory analysis of tank contents confirmed that the tank was active; therefore, raw sludge feedings of 5,000 to 10,000 g.p.d. were made to sustain its activity.

Up to January 9, 1953, the No. 1 primary digester had received a total of 14,000 lb. of lime, with only slight improvement in pH and alkalinity noted. The favorable condition ex-

isting in the No. 3 secondary tank suggested the advisability of transferring as much of its contents as could be spared to the sluggish No. 1 primary. Two transfers of 700,000 gal. each were made within the next 38 days. On February 15, 1953, the pH was 6.85, with slight foaming evidenced at the gas dome. Raw sludge feedings were stopped and two days later laboratory analysis of the tank contents confirmed the fact that the tank was "in." Gas analysis on this date showed 25 per cent carbon dioxide and 70 per cent methane.

Operating results as taken from typical monthly records show raw sludge loadings of 4.102 m.g. to No. 1 digester and 3.811 m.g. to No. 2 digester. The loadings averaged 6.13 per cent total solids, of which 73.6 per cent was volatile. Representative digested sludge removed from the secondaries for disposal averaged 11.41 per cent total solids, of which 48.5 per cent was volatile. Combined solids destroyed in the No. 1 and No. 3 tank combination amounted to 1,024,207 lb., while that of the No. 2 and No. 4 digesters was 951,539 lb. From this digestion a total of 30,071,600 cu. ft. of sludge gas was measured through the gas meters, with an additional unknown amount venting through the relief valves.

No serious operational difficulties have been experienced, due entirely to the excellent control maintained by the laboratory force. The use of recirculation nozzles located in the top of the primary tanks at elevation 144.00 has been most effective in preventing the formation of any scum blanket, with only slight annoyance at the secondaries from plugged overflow lines at the venturi-type plug valves.

Gas System

The gas system was readied and put into service on April 22, 1953. When all gas-operated units (including the auxiliary heating boiler, gas storage sphere, straight gas and dual-fuel generating units, dual-fuel blower engine, plus other small gas-fired heaters) are required, total gas demand is 489,000 cu. ft. per day. As this condition has only been approached on one occasion, surplus gas in excess of 500,000 cu. ft. per day is disposed of at the six waste gas burners.

The system operates at a pressure of 5 in. water column, with constant attention to the condensate drip traps required. All gas is burned as collected, without the aid of scrubbers. Weekly tests for hydrogen sulfide content are made, with average readings of 5 to 15 grains per 100 cu. ft. being obtained. Some evidence of iron sulfide deposits in the gas piping system is apparent. All flame traps, gas pressure relief valves, and regulating valves are inspected on a routine schedule. On one occasion 460 gal. of condensate were drained from the gas header.

A storage sphere of 90,000-cu. ft. capacity, arranged to feed gas back into the system if needed during failure or low gas production, is maintained charged at 30 p.s.i., but has not been used to date due to the quantity of gas produced exceeding maximum demands.

The entire system is in use and operating in a most sastisfactory manner.

Outfalls

A 12-in. submarine line, provided for the disposal of digested sludge, extends from the Nut Island plant to a point off Long Island, a distance of about 4 mi. All sludge withdrawn from the secondary digestion tanks is pumped through this line, together with large quantities of sewage effluent, added for dilution and flushing purposes. The line has worked well in handling digested material, with maintenance limited to circulating a flexible pipe cleaner through the line once each year.

The effluent outfalls include the three lines constructed with the original

works in 1904 and the new 60-in. offshore diversion outlet constructed to handle peak flows during extreme storm and tidal conditions.

Two of the original lines extend offshore approximately 5,800 ft. and handle normal flows up to 150 m.g.d. A third outlet, located only 1,400 ft. offshore, is used only when the capacity of the other lines is exceeded. During early stages of construction two of these lines were modified by placing specially designed precast concrete domes over the upturned outfall elbows and then locating 84 concrete beams radially around the rim of the domes. In March 1952, when these lines would no longer handle their rated capacity, it was necessary to remove the concrete beams to relieve the stoppage caused by an accumulation of construction debris, rags, and other solids which had collected during their temporary use.

Chlorination

Chlorine storage and handling facilities for 45 1-ton containers are located in the Administration Building. Four 6,000-lb.-per-day hydraulically-operated chlorinators, equipped for manual control or automatic proportioning, are located in the Main Building. The pre-chlorination diffuser is located just upstream from the main screens; the post-chlorination diffuser is located in the effluent conduit some 5,800 ft. before the point of discharge, which permits the outfalls to serve as chlorine contact chambers.

Pre-chlorination to a subresidual has been used for odor control, for protection of equipment, and as an aid to the treatment process whenever incoming sewage approaches septic conditions. Post-chlorination is conducted as directed by the Massachusetts Department of Public Health, usually from June to October, with sufficient dosage to maintain a minimum residual of 0.15 p.p.m. The chlorine demand for the 1952 and 1953 recreational seasons averaged 6 p.p.m. During 1953 post-chlorination was effected from June 4 to September 17, inclusive. Combined pre- and post-chlorination for the year required 355 tons of chlorine to maintain an average residual of 0.16 p.p.m. in the effluent and a bacterial density of 14,600 M.P.N. per 100 ml.

To insure uninterrupted operation during the recreational season all chlorination equipment is thoroughly overhauled prior to use each season.

Maintenance Procedures

Maintenance procedures, including alterations, improvements, and major overhauls, have been carried out by plant personnel. Mechanical and electrical repairs are assigned to various members of the maintenance force by written work order, which is returned to the head mechanic with comments and signature of the individual performing the work. From these work orders a card system is maintained on every piece of equipment in the plant. The luxury of consulting this card system as a reminder of what needs to be done today has not been realized to date. Nevertheless, after nearly two years the conversion from handling only emergency breakdowns and failures to normal preventative maintenance is well underway.

Reference

1. Kennison, Karl R., "Sewage Works Development in the Massachusetts Metropolitan District." THIS JOURNAL, **22**, 4, 477 (Apr., 1950).

PUMP PACKING AND DIGESTER CLEANING HINTS

By J. E. Meers

Superintendent, Sanitary District of Bloom Township, Chicago Heights, Ill.

During the period 1952–4, the sewage treatment plant of the Sanitary District of Bloom Township (Ill.) has undergone a complete physical rehabilitation. In addition, many sorely needed improvements have been made in operation and maintenance procedures.

Starting point in the rehabilitation effort was a public relations program, whose record speaks for itself. In April 1952, when the District held a bond election for expansion of the plant, the bond issue was defeated by a vote of approximately 3 to 1. By November 1953, however, when another election was held, the vote was approximately 4 to 1 in favor of the expansion program. This change in attitude was a direct result of the extensive and careful planning of the public educational program and the fine cooperation of civic groups.

As regards the over-all program, it is worth passing along to other operators that any program can be successful if the operator applies himself diligently, evinces a devoted interest to his work and problems, is not afraid of long hours, and has a world of patience. These seem to be the ingredients of success.

Maintenance Items

Although each plant has its own peculiar problems, some of the problems are common to many. Among these are the matters of packing for both centrifugal and piston pumps and removal of heavy silty material from the bottom of sludge digestion tanks during cleaning.

Neoprene Hose Packing

At the Bloom Township plant the piston-type sludge pumps used to require repacking about every two weeks. To fit the different pumps, neoprene heavy hose in ½-in. and ⅜-in. outside diameter size was purchased from an auto supply store. After cutting to the lengths needed, a ring of the hose was put in the bottom of the stuffing box, then two rings of standard packing, and then another ring of neoprene hose. Since using the hose, these pumps haven't been repacked in eight months.

The centrifugal pumps also are packed in the same manner, with the neoprene seals outlasting ordinary packing about 5 to 1.

Digester Silt Removal

With inadequate grit removal equipment, it becomes necessary to dewater the digester each year. This tank has a floating cover, a 65-ft. diameter, 20-ft. sidewalls, a cone bottom, and a capacity of 75,000 cu. ft. The 500,800 gal. of sludge to be removed contained considerable grit, silt, clay, etc.

After two weeks of pumping, the remaining sludge in the digester was so heavy that it was impossible to pump it. Furthermore, there was no way of keeping it agitated by the use of fire hose. By coincidence, just at this time the program at a local Rotary Club meeting included a demonstration and talk on sodium hexametaphosphate. Among the points mentioned was the use of this material in oil drilling operations to "liquefy" clay and keep it in suspension. Further conversation with the engineer of a local chemical manufacturer led to use of some sodium hexametaphosphate in the digester on an experimental basis.

At 4 PM on September 15, 1953, 3 lb. of chemical was pumped into the

bottom center of the digester through the sludge sampling pit. No additional water was introduced, but the tank was then left undisturbed over night. The next morning there was evidence of the sludge "liquefying" and it was suggested that a 2-in. water pipe be placed in the tank center to keep the sludge agitated around the drawoff pipe. About noon of this day pumping was started to remove this material—without difficulty—to the lagoons.

About 4 PM on September 16, a second 3-lb. dose of the chemical was added in the same manner. Although the material consisted of sand, grit, grease, and very heavy inorganic solids and had a solids content of approximately 20 per cent, it moved readily under washing with fire hoses for pumping to the lagoons.

The chemical used is sodium hexametaphosphate, obtainable at most grocery stores under the trade name "Calgon." The manufacturers, however, recommend that the material not be used with sludge that later will be filtered by rotary or vacuum filters. Nevertheless, under the conditions of its use in the case described, the chemical performed successfully.

TIPS AND QUIPS

Grease Removal from Sludge Pipes

Unsuccessful experience in removing grease from sludge lines with normal pipe cleaning tools led to use of live steam for that purpose at the Waterbury, Conn., sewage treatment plant. According to Superintendent Walter M. Kunsch, the steam did a good job, but created quite a mess to clean up, as the method was restricted to runs of not more than 40 ft. and in at least one instance there are several such runs on a single pipeline from the raw sludge pumps to the sludge storage tanks.

The unpleasant clean-up job on some of the floor areas where the grease removed by steam had to be dropped, as well as the time-consuming feature of the steam-cleaning method, led to a suggestion that a solid "dam" of raw sludge filter cake be formed in the pipe, then be forced through the entire run of pipe to the storage tanks by applying water pressure behind it. Theoretically, this should force the grease ahead of the "dam" and into the storage tanks.

Happily, the suggested method worked, forcing a long "snake" of grease into the storage tanks through about 150 ft. of 8-in. cast-iron pipe. The storage tanks are messy anyhow and lend themselves to removal of the grease much better than do the floor areas previously involved. Moreover, the method is much quicker than the steam method.

At first high-pressure (100 p.s.i.) city water was used, but later the plant flushing water (35 p.s.i.) was used with good results.

Hand Lift Truck

The advantages of a lift truck and the portability of a hand truck have been combined in a handy "Shop Caddy" by Precision Equipment Co., 3714 N. Milwaukee Ave., Chicago 41, Ill. Claimed to be the ideal tool for loading and unloading trucks, for stacking containers, and for other heavy lifting, the unit is essentially a light hand truck with hand-operated hydraulic lift.

Units have a capacity of 500 lb. and a lifting height of 36 in. Other units with capacities up to 1,000 lb. and lifting heights up to 78 in., both

hand-operated and power motivated, also are available.

Cleaner Air Week

Observance of Cleaner Air Week from October 24 to October 30 is urged as only a start for year-round attention to the need for control of air pollution from all its sources. According to the Air Pollution Control Association, sponsor, the special observance is intended to advertise accomplishments in this field to date, to stress the scope and complexity of the problem, and to enlist the active participation of all in air pollution prevention and abatement.

Pipe Markers

Self-sticking, all-temperature pipe markers are available in a large variety of legends on the approved American Standards Association background colors and in various printing styles. Also available are directional arrows and solid color pipe markers of the same self-sticking type. Information may be obtained from W. H. Brady Co., 727 W. Glendale Ave., Milwaukee 12, Wis.

Plant Playground Improves Public Relations

When Superintendent Andy Wahl and his crew at the Boise, Idaho, sewage treatment plant got tired of watching and worrying about the youngsters playing in the street and around a nearby mill pond, they did something about it. With materials donated by local business firms, the plant's night crew welded pipe together to make the equipment, which was "planted" in concrete by the day crew. Some grass, a few bushes, and some paint have turned the area into a neighborhood playground so popular that it has been impossible to find open time enough to apply more than a prime coat of paint.

Here is the "Good Neighbor Policy" at work, right in the plant's own back yard!

New Jersey Operators Exam

Persons wishing to take the next Sewage Plant Operator Examination in New Jersey must file an application with the Bureau of Examination and Licensing, New Jersey State Department of Health, Trenton, N. J., by November 10, 1954.

No Troubles Worth Mentioning

Have you ever felt that your troubles were only frustrations, multiplying rapidly as time went on? Then you'll appreciate the feelings of one neighbor whose story is being told by J. E. Meers, Superintendent of the Bloom Township (Ill.) Sanitary District.

While the neighbor was out of town on business, a contractor started digging a sewer on his property without obtaining permission. As a result the driveway and walk were torn up and the whole place was a mess. When his wife called by long-distance telephone and gave him the gory details, the neighbor immediately started for home, arriving there about midnight. Since there no longer was a driveway, he parked his car in the street and with loaded arms (radio, briefcase, suitcase, etc.) climbed over a pile of dirt and fell into the ditch.

Funny? Yes, but it could have been tragic. And to top it all off the neighbor was awakened at 2 AM by a loud knocking on his door, said knocking being the police. What did they want? Only to have him remove his car from the street, while at least five pieces of the contractor's machinery blocked the road. Such is life!

Reviews and Abstracts*

Wastes from Potato Starch Plants. By T. W. Ambrose and C. O. Reiser. *Ind. Eng. Chem.*, **46,** 1331 (1954).

This paper reports a comprehensive and detailed summary of the wastes from several potato starch plants near the University of Idaho. A ton of potatoes produces wastes with a population equivalent of 350 on the B.O.D. basis. If the potato pulp can be dried for food, the waste load may be reduced 40 per cent.

The potato protein waste contains about 1.7 per cent solids, of which 40 per cent is protein. Chemical or heat treatment gives good removal of the protein, but the sludge is hard to handle. Recirculation of the wash water is suggested.

Spectrophotometric Determination of Urea. By G. W. Watt and J. D. Chrisp. *Anal. Chem.*, **26,** 452 (1954).

The method for determining urea is based on the yellow-green color produced when *p*-dimethylaminobenzaldehyde is added to urea in dilute hydrochloric acid solution. There is no interference from the ammonium ion. The color requires 10 min. to develop, but is stable thereafter.

Rapid Determination of Nitrates and Nitrites. By J. L. Nelson, L. T. Kurtz and R. H. Bray. *Anal. Chem.*, **26,** 1081 (1954).

This technique is designed primarily for determining combined oxidized nitrogen in soils. The reagent is a mixture of dry chemicals which may be added to a solution of nitrate and nitrite. The nitrate is reduced by powdered zinc in the presence of a manganese sulfate to nitrite.

The nitrite from the reducing step and that present originally is determined with sulfanilic acid and alpha (α) naphthylamine. The color is compared with standards prepared in the same manner. The sample is first adjusted to ph 2.0 with 20 per cent acetic acid for maximum color.

Persistence of Pyridine Bases in Polluted Water. By M. B. Ettinger, R. J. Lishka, and R. C. Kroner. *Ind. Eng. Chem.*, **46,** 791 (1954).

Pyridine bases are not readily used as a source of carbon by sewage organisms. Once an adequate innoculum has been developed, the pyridine and picoline can be used rapidly. A polluted river seed may use the compounds without requiring repeated doses. R. S. Ingols

Decontamination of Radioactivity Contaminated Water by Slurrying with Clay. By W. J. Lacy. *Ind. Eng. Chem.*, **46,** 1061 (1954).

A slurry of 1,000 p.p.m. clay is able to remove high percentages of cerium, praseodymium, zirconium, niobium, barium, lanthanum, strontium, and yttrium. The clay should be added before coagulation. It is not effective in removing iodine.

R. S. Ingols

Hydraulic Research in the United States 1954. Misc. Publ. 210, Nat. Bur. of Standards. 193 pp. Price, $1.25 (1954). (Order from Govt. Printing Office, Washington 25, D. C.)

This publication contains information compiled from reports by the various hydraulic and hydrologic laboratories in the United States and Canada. Reported projects include private, university, and government supported research. A large number of the projects listed in this volume are reported for the first time.

Projects are reported by title and carry a number which is kept throughout the project history. Other information includes the project sponsor, project correspondent, nature of the project, a brief description,

* Please send to Federation headquarters all periodicals, bulletins, special reports, etc., which might be suitable for abstracting in This Journal. Publications of public health departments, stream pollution control agencies, research organizations, and educational institutions are particularly desired. Address such material: Federation of Sewage and Industrial Wastes Assns., 325 Illinois Bldg., Champaign, Ill.

the present status, results, and publications. H. P. O.

Methods for Detecting the End-Point in the Titration of Iodine with Thiosulphate. By G. Knowles and G. F. Lowden. *Analyst*, **78,** No. 924, 159 (Mar., 1953).

A simple amperometric circuit proved the best indicator of the end point in the titration of iodine with thiosulfate. Starch indicator can lead to errors, on the low side, of the order of 20 to 40 μg. of iodine in volumes of 50 to 200 ml., and sodium starch glycollate is even less accurate. The dead-stop end-point method and the derivative polarographic method are both less satisfactory than the amperometric method. Authors

Some Chemical and Bacterial Characteristics of Bottom Deposits from Lakes and Estuaries. By L. A. Allen, J. Grindley, and Eileen Brooks. *Jour. Hygiene*, **51,** 2, 185 (June, 1953).

Chemical and bacteriological examination of muds from sources differing widely in the degree of pollution to which they were subject showed great differences in the contents of carbon, nitrogen, and sulfide. These differences were not correlated with differences in the severity of fecal pollution. The amount of organic matter available for growth of microorganisms in the mud of different depths was not reflected in the values for organic carbon. A convenient index of this factor was obtained by measuring the volume of gas evolved during anaerobic digestion over a prolonged period of incubation. The rate of evolution was increased by the addition of an inoculum of digested sludge from a sewage works.

Sulfate-reducing bacteria appeared to be of two different types. In samples of mud from fresh-water lakes much higher counts were usually obtained in a medium containing comparatively low concentrations of inorganic salts and of lactate than in a medium containing much higher concentrations of these constituents. In samples from locations where conditions were more saline the reverse was usually true.

Counts of *B. coli* and of *Strep. faecalis* together probably constitute the best index of fecal pollution in the examination of samples of mud. These organisms are, however, largely confined to the surface layers. H. P. O.

BOOKS, REPORTS, AND PAMPHLETS

First Annual Report, Alexandria (Va.) Sanitation Authority. 18 pp. (Feb., 1954).

Treatment of Trade Wastes with Dolomitic Lime. The Finishing Lime Association of Ohio, Toledo, Ohio. 8 pp. (1954).

Ramapo and Mahwah River Drainage Basins. Lower Hudson River Series Report No. 4, N. Y. State Water Poll. Control Board, Albany, N. Y. 43 pp. (1954).

Hudson River. Lower Hudson River Series Report No. 5, N. Y. State Water Poll. Control Board, Albany, N. Y.

Deals only with the main stream from Bear Mountain Bridge to the Mohawk River. 73 pp. (1954).

Saw Mill River Drainage Basin. Lower Hudson River Series Report No. 6, N. Y. State Water Poll. Control Board, Albany, N. Y. 25 pp. (1954).

Report of Activities of the Tennessee Stream Pollution Control Board, July 1, 1952–June 30, 1953. Tennessee Stream Pollution Control Board, Nashville, Tenn. 22 pp. (1954).

Chemical Character of Surface Water in Pennsylvania, 1949 to 1951. By Norman H. Beamer. Pennsylvania Dept. of Commerce, State Planning Board, State Capitol Building, Harrisburg, Pa. (Also available from N. H. Beamer, U. S. Geological Survey, Room 1302 U. S. Custom House, Philadelphia 6, Pa. (Nov., 1953).

Second Industrial Wastes Forum. Interstate Commission on the Potomac River Basin, 203 Transportation Bldg., Washington 6, D. C.

Papers presented at the forum, held at Hagerstown, Md., on November 19, 1953.

Book Reviews

Gewerbliche und Industrielle Abwässer. By Friederich Sierp. Springer-Verlag, Berlin, Germany. 555 pp. Price, DM 49.50 (1953).

This remarkable book, written by one of the leading chemists in the sewage works field, is probably the most complete work yet published on industrial wastes. Dr. Sierp for many years has been chief chemist of the Ruhrverband, the water control district serving Germany's most important industrial region.

The book is not divided into the usual chapters, but is made up of five main sections: A. General Introduction (6 pp.), B. Effects of Industrial Wastes on Municipal Sewage Works (32 pp.), C. Influence of Industrial Wastes on the Stream (17 pp.), D. Preliminary Planning of Industrial Wastes Treatment Plants (4 pp.), and E. Types of Wastes (481 pp.) By far the greatest emphasis is given the detailed coverage of almost every conceivable waterborne industrial waste in Part E. The origin and characteristics of the wastes are described, together with methods of by-products recovery and residual treatment.

Documentation is principally by German and American literature, although some reference is also made to experience in Britain, Japan, and in other European countries. Most of the 174 illustrations are flow diagrams and drawings of treatment units and devices, which are of definite practical interest to the reader. A 15-page index enhances the reference use of the book.

Dr. Sierp has been eminently successful in his aim to produce a handbook of industrial wastes control that is of value to all professional elements concerned with water pollution problems. W. H. W.

Proceedings of the Eighth Industrial Waste Conference. *Eng. Bull.*, **38**, No. 1 (Extension Series No. 83). Purdue Univ., Lafayette, Ind. 562 pp. Price, $2.50 (Jan., 1954).

The papers included in the "Proceedings" are those presented at the Eighth Conference, held May 4–6, 1953, as follows:

"Industrial Waste Treatment Plant for Allison Division of General Motors Corporation," by L. I. Couch.

"Treatment of Municipal and Industrial Wastes by Flotation," by Robert A. Baum and George E. Hurst.

"Air Pollution with Industrial Wastes," by H. C. Ballman.

"Operations of Experimental Trickling Filters on Oil-Containing Waste Waters," by R. J. Austin, W. F. Meehan, and J. D. Stockham.

"Recent Developments in the Design of Small Milk Waste Disposal Plants," by J. P. Horton and H. A. Trebler.

"Disposal of Antibiotic Spent Beers by Triple-Effect Evaporation," by Keith H. Edmondson.

"A Pollution Prevention Committee," by G. A. Collins, Jr.

"Comparison of Flotation and Sedimentation in Treatment of Industrial Wastes," by A. A. Kalinske and R. R. Evans.

"Systems for the Destruction of Cyanide Wastes at Buick Motor Division," by R. J. Brink.

"The Toxicity of Chromium," by R. S. Ingols.

"Methods for Treating Metal Finishing Wastes," by Hubert S. Kline.

"Treatment of Petrochemical Wastes," by C. O. Huntress.

"Development of Vegetable Cannery Waste Disposal by Land Irrigation," by Helmer Monson.

"The Persistence of Lignin in River Waters," by R. C. Kroner and W. Allan Moore.

"New Items in Milk Waste Saving and Treatment," by Frank J. McKee.

"Beet Sugar Waste Lagooning," by Harvey G. Rogers and L. H. Smith.

"Soil Conservation and Stream Pollution," by Gunnar M. Brune.

"Organizing a Plant for Over-All Waste Control," by R. B. Parks.

"Studies of the Character and Treat-

ment of Wastes from Duck Farms," by Wallace W. Sanderson.

"Fume Disposal by Catalytic Combustion," by R. J. Ruff.

"Design of Settling Units for Removal of Inert Suspended Solids," by R. W. Simpson and William Garlow.

"A Second Waste Treatment Plant," by Marvin A. Pratt.

"The Determination and Persistence of Furfural in River Waters," by M. B. Ettinger, R. J. Lishka, and W. A. Moore.

"Plating Waste Treatment," by C. F. Paulson.

"Statistical Evaluation of Packinghouse Waste Data," by Conrad P. Straub.

"Industrial Wastes Engineering—Flow Meters and Chemical Feeders," by Henry F. Munroe.

"Experimental Treatment of Citrus Waste Water," by Robert R. McNary, Richard W. Wolford, and Marshall H. Dougherty.

"Thermophilic Digestion of Monosodium-Glutamate End Liquor," by Herman A. Pearson, Carl J. Weinberg, and Wilbur W. Whitsell.

"Spray Irrigation at Morgan Packing Company," by Perry E. Miller.

"Shortcomings in Present Stream Pollution Control Practices Predict Areas for Future Work," by Kenneth S. Watson.

"Some Important Biological Effects of Pollution Often Disregarded in Stream Surveys," by Clarence M. Tarzwell and Arden R. Gaufin.

"An Evaluation of Our Water Resource With Specific Reference to the State of Washington," by E. F. Eldridge.

"The Treatment of Wastes at the Rohm & Haas Company," by F. Majewski.

"Aerobic Treatment of Wastes High in B.O.D. Concentration," by Harry W. Gehm.

"Instrumentation and Automatic Control Applications in the Activated Sludge Treatment of Industrial Wastes," by W. Wesley Eckenfelder, Jr.

"Applications of Submerged Combustion in Industrial Waste Treatment," by William I. Weisman.

"Pilot-Plant Studies of Air Flotation of Oil Refinery Waste Waters," by Gerard A. Rohlich.

"Dairy Waste Treatment Pilot Plant," by R. Rupert Kountz.

"Borax as a Preservative of Dairy Waste for the B.O.D. Test," by Lenore Jasewicz, Nandor Porges, and Sam R. Hoover.

"Removal of Radioisotopes from Waste Solutions by Soils—Soil Studies with Conasauga Shale," by T. W. Brockett, Jr., and O. R. Placak.

"Waste Disposal and Stream Pollution Control," by Bruce A. Barr.

"Removal of Radioisotopes from Waste Solutions—Soil Suspension Studies," by Conrad P. Straub and Herman L. Krieger.

"The Disposal of Industrial Effluent by Woods Irrigation," by John R. Mather.

"Control of Radioactive Airborne Wastes," by Richard D. Coleman and Leslie Silverman.

"Disposal of Radioactive Wastes at Argonne National Laboratory," by W. A. Rodger, P. Fineman, and H. Gladys Swope.

"Biological Oxidation of Synthetic Organic Chemicals," by E. J. Mills, Jr., and Vernon T. Stack, Jr.

"New Developments in Packinghouse Waste Treatment," by George J. Schroepfer.

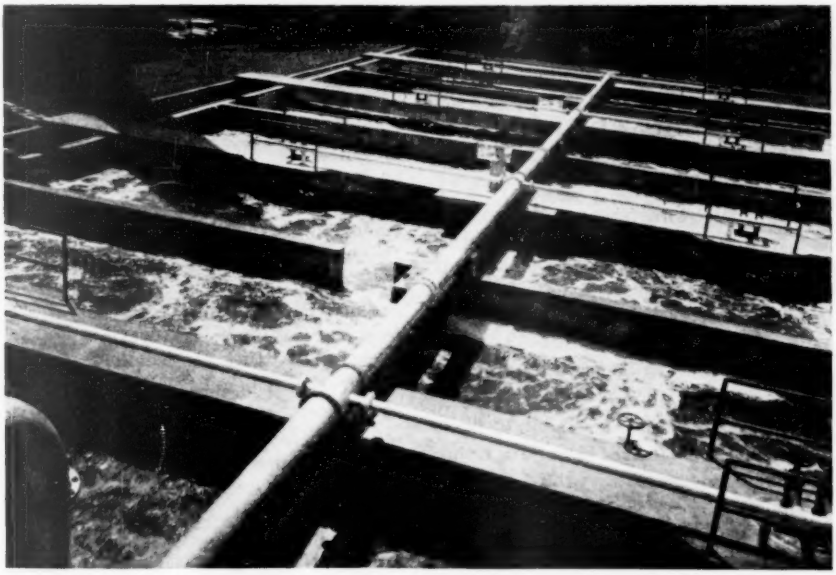
A 22-page cumulative index for the first eight "Proceedings" is included.

H. P. O.

The Municipal Year Book, 1954. CLARENCE E. RIDLEY AND ORIN F. NOLTING, editors. International City Managers' Assn., Chicago, Ill. 613 pp. Price $10.00 (1954).

In addition to bringing the regular sections up-to-date, the 1954 (21st) edition of this municipal administrators' standard reference contains new sections on urban counties, fringe area services, sewage service charges, and refuse collection and disposal practices. As in previous editions, considerable emphasis is placed on the more significant municipal events and developments of the previous year.

H. P. O.



Diffusair Aeration Increases Plant Capacity

The replacement of mechanical aeration equipment with Walker Diffusair units enabled Birmingham, Michigan, to substantially increase the capacity of their aeration tanks without the expense of constructing additional tanks. Note that this installation is now cross roll circulation giving excellent tank roll without the use of top deflecting baffles.

Diffusair aeration equipment is designed to accomplish intimate mixing, oxygenation and agitation of the tank liquor. The effective performance of these functions results in greater tank turn-over and increased agitation and oxygenation plus improved over-all plant operation.

Many existing diffused air installations are now improving their operation and reducing aeration costs by re-equipping present air manifolds with this modern Diffusair equipment.

For economical and efficient aeration, investigate Walker Process Diffusair equipment.

WALKER PROCESS

WALKER PROCESS EQUIPMENT, INC.
Factory — Engineering Offices — Laboratories
Aurora, Illinois

Proceedings of Member Associations

NEW ENGLAND SEWAGE AND INDUSTRIAL WASTES ASSOCIATION

The 25th Anniversary Meeting of the New England Sewage and Industrial Wastes Association was held at the Hotel Somerset, Boston, Mass., on April 22–23, 1954. The registered attendance was 170, including 33 ladies.

Papers were presented as follows:

"Safety in Sewage Works Operation," by LeRoy W. VanKleeck, State Department of Health, Hartford, Conn.

"Overloads on Shear Pins," by Walter M. Kunsch, Superintendent of Sewage Treatment, Waterbury, Conn.

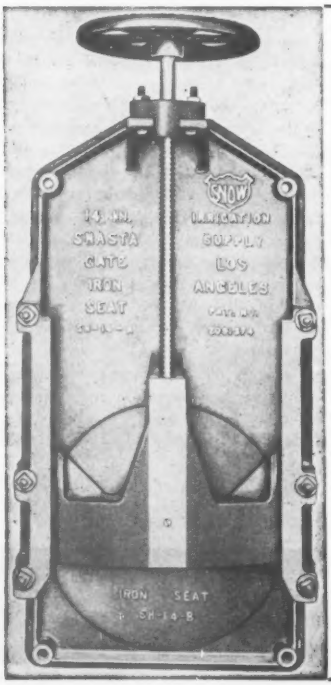
"Synthetic Detergents: Their Frothing Tendency and Influence on Oxygen Transfer During Aeration," by William O. Lynch, Research Assistant, and Clair N. Sawyer, Professor of Sanitary Engineering, Massachusetts Institute of Technology.

"Synthetic Detergents: Influence of Chemical Structure Upon Biological Degradation Under Aerobic Conditions," by Richard H. Bogan, Research Assistant, and Clair N. Sawyer, Professor of Sanitary Engineering, Massachusetts Institute of Technology.

"Process Chemical B.O.D. Sources in Cotton Finishing Wastes," by Joseph W. Masselli, Research Chemist, and M. Gilbert Burford, Consultant-Supervisor, Connecticut State Water Commission Research Laboratory, Wesleyan University, Middletown, Conn.

"The Mansfield Story—An Experi-

(*Continued on page 416a*)



SNOW GATES
for
SEWAGE TREATMENT PLANTS

All types of cast iron gates manufactured in either square or circular opening in sizes up to and including 72 inches.

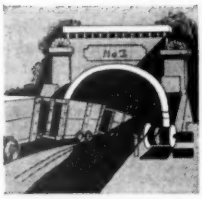
ALL SNOW GATES and Lifts are "Parkerized" for protection against rust and corrosion.

Over 40 years continuous service to the industry.

We will be pleased to quote on any type of water controlling equipment.

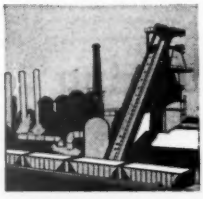
SNOW GATES & VALVES
2437 East 24th Street Los Angeles 54, Calif.

OUR INTEGRATED OPERATION PERMITS MAXIMUM CONTROL OF QUALITY

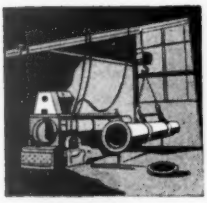


Ore and Coal Mines

Coke Ovens



Blast Furnaces



Pipe Plants

U.S. cast iron PIPE

FOR WATER, GAS, SEWERAGE AND INDUSTRIAL SERVICE

From start to finish, our wholly integrated operation makes it possible for us to control quality at every step. Beginning with our mines, quarries and blast furnaces. Ending with our modern casting machines and laboratories.

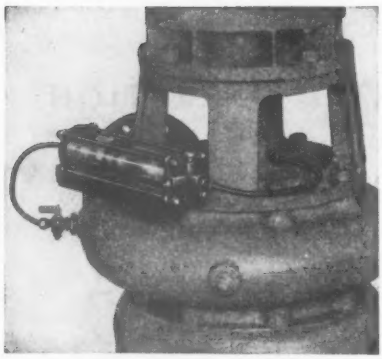
Responsibility for quality rests squarely on the shoulders of a wholly integrated producer. He shares that responsibility with no one.

In addition to being able to control the quality of pipe-making raw materials at their sources, our Quality Control of pipe production gives further assurance to customers that the quality level of U. S. Cast Iron Pipe is in excess of standard specifications. Our pipe is produced to our own quality control specifications, more exacting than the established specifications under which cast iron pipe is normally purchased.

U. S. PIPE & FOUNDRY COMPANY

GENERAL OFFICES: BIRMINGHAM 2, ALABAMA

A wholly integrated producer . . . from mines and blast furnaces to finished pipe.



Surer Gland Lubrication
for Centrifugal Pumps

THE Z-F GREASE SEAL

Eliminates that trouble spot where shaft enters casing. Applies constant positive lubrication to packing and shaft—automatically. Excessive heat, rapid wear, leakage and scoring will disappear as the Grease Seal applies a constant flow of lubrication when pump starts until it stops—automatically. Many other advantages, too. Write for complete description and price.

Zimmer and Francescon, Moline, Ill.

ence in Public Relations," by Harry F. Ahern, Manager, Mansfield Plant, Hercules Powder Co., Mansfield, Mass.

"First Two Years of Operation and Maintenance of the Nut Island Sewage Treatment Plant," by Joseph B. Hanlon, Superintendent of Sewage Treatment Plants," Metropolitan District Commission, Boston, Mass.

"Round Table Discussion—Problems in Industrial Wastes Treatment."

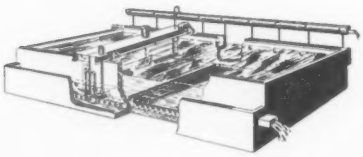
An inspection trip was made to the Boston Metropolitan District's Nut Island sewage treatment plant at Quincy.

At the business meeting, W. S. Wise, of Hartford, Conn., was elected as FSIWA Director.

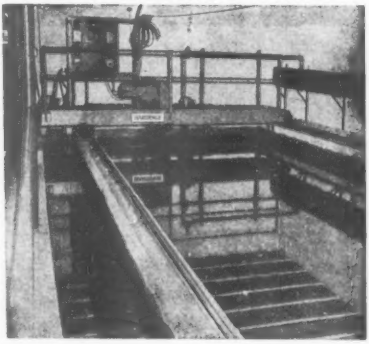
STEPHEN M. HURLEY, JR.,
Secretary-Treasurer

It CLEANS ITSELF while filtering . . .

THE HARDINGE AUTOMATIC BACKWASH SAND FILTER



Here is a sand filter which cleans itself—automatically—with no interruption whatever to the filtering operation. No shutdown or changeover is necessary while cleaning is in progress. The secret lies in its special, compartmented filter bed and traveling backwash mechanism which automatically cleans one compartment at a time. May be used for plant supply water or for waste water treating. Write for Bulletin 46-A-16.



ABW Filter in municipal water treating plant

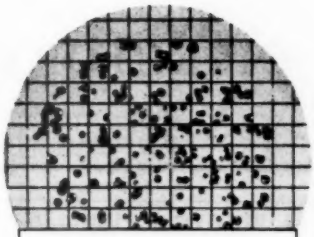
HARDINGE
COMPANY, INCORPORATED

YORK, PENNSYLVANIA · 240 Arch St. · Main Office and Works

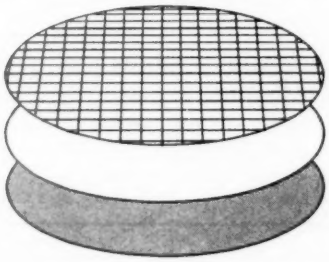
New York · Toronto · Chicago · Hibbing · Houston · Salt Lake City · San Francisco

Are you using MF Techniques for bacteriological analysis?

Isopor dehydrated nutrient schedules save laboratory time and expense



MF membrane with colonies of E. coli after 18 hours of incubation using ISOPOR dehydrated nutrient schedule.



A .... Molecular filter membrane, Type HA, 47 mm diameter, grid marked.

B .... Thin leaf of porous paper, impregnated with generally or partially stimulating nutrient.

C .... Disk of blotting paper, impregnated with inhibitory or secondary nutrient.

The known absorption qualities of papers used in ISOPOR Scheduled Nutrient Packs deliver nutrients to cultures on a time-controlled basis.

The use of ISOPOR Dehydrated Nutrient Packs allows users of MF techniques for hydrosol analysis to eliminate practically all intermediate steps in bacteriological analysis. After filtration, membranes are placed directly on rehydrated ISOPOR pads in a Petri dish and incubated. No intermediate steps are required. Tests are complete in 16-18 hours with only two pieces of sterile equipment (MF holder and Petri dish).

ISOPOR DEHYDRATED SCHEDULED NUTRIENT PACKS

Molecular filter membranes, complete with dehydrated nutrient schedules, sterile packed in polyethylene envelope.

ENDO . . . . . *(Coli-Aerogenes group)*
E.M.B. . . . . *(Coli-Aerogenes differentiation)*
GENERAL I . . . . . *(General nutrient with redox indicator)*
GENERAL II . . . *(General nutrient with redox indicator and fungus-yeast inhibitor)*
YEAST . . . . . *(Yeast-bacteria differentiation)*

ISOPOR STERILE MF PACKS . . . *Same as above, except with absorbent pad for impregnation with liquid nutrient.*

For further information, write to:

AG CHEMICAL COMPANY, INC.

Box 65C • Pasadena, California

See ISOPOR Ad on Pages 390a, 391a

DIRECTORY OF ENGINEERS

(Continued through page 423a)

ALBRIGHT & FRIEL, INC.
FRANCIS S. FRIEL
Consulting Engineers
WATER, SEWAGE AND INDUSTRIAL WASTE PROBLEMS
AIRFIELDS, REFUSE INCINERATORS
INDUSTRIAL BUILDINGS
CITY PLANNING — VALUATIONS
REPORTS — LABORATORY
Suite 1509-18, 121 S. Broad St. — PHILADELPHIA 7

ALVORD, BURDICK & HOWSON
Engineers
Charles B. Burdick — Louis R. Howson
Donald H. Maxwell
Water Works, Water Purification, Flood Relief, Sewerage, Sewage Disposal, Drainage, Appraisals, Power Generation
Civic Opera Building — Chicago

ANDERSON-NICHOLS & Company
Consulting Engineers
Water Supply, Distribution and Treatment, Industrial Waste Treatment, Sewage Collection and Disposal, Refuse Collection and Disposal, Drainage, Highways and Bridges.
Concord, N. H. — Boston 14 — Baltimore, Md.

JOHN J. BAFFA
Consulting Engineer
Sewerage & Sewage Treatment
Industrial Wastes Treatment
Design Plans & Specifications
Investigations & Rate Studies
75 West Street — New York 6, N. Y.

MICHAEL BAKER, JR., Inc.
The Baker Engineers
Civil Engineers, Planners, and Surveyors
Municipal Engineers—Airport Design—Sewage Disposal Systems—Water Works Design and Operation—Surveys and Maps—City Planning—Highway Design—Construction Surveys—Pipe Line Surveys
Home Office: Rochester, Pa.
Branch Offices: Jackson, Miss. Harrisburg, Pa.

BAXTER AND WOODMAN
Civil and Sanitary Engineers
Water Supplies — Water Treatment
Sewer Systems — Sewage Treatment
Industrial Waste Treatment
Investigations
P. O. Box 67 — Crystal Lake, Illinois

BLACK & VEATCH
Consulting Engineers
SEWAGE - WATER - ELECTRICITY - INDUSTRY
Reports, Design, Supervision of Construction
Investigations, Valuation and Rates
4706 Broadway — Kansas City 2, Missouri

W. H. & L. D. BETZ
Consulting Engineers
Industrial Waste
Industrial Water
Analysis — Design
Investigations — Operation
Gillingham & Worth Sts. — Philadelphia 24, Pa.

BOGERT AND CHILDS
Consulting Engineers
CLINTON L. BOGERT — FRED S. CHILDS
IVAN L. BOGERT — DONALD M. DITMARS
ROBERT A. LINCOLN — CHARLES A. MANGANARO
WILLIAM MARTIN
Water & Sewage Works — Refuse Disposal
Drainage — Flood Control
Highways and Bridges — Airfields
624 Madison Ave., New York 22, N. Y.

Take advantage of the services of these outstanding consultants!

BOWE, ALBERTSON & ASSOCIATES
Engineers
Sewerage—Sewage Treatment
Water Supply—Purification
Refuse Disposal—Analyses
Municipal—Industrial Projects
Valuations—Reports—Designs
110 William Street New York 7, N. Y.

BROWN AND BLAUVELT
Consulting Engineers
Water Supply
Sewer Systems
Sewage Disposal Plants
Industrial Wastes Problems
Airports
Highways
Industrial Buildings
Railroads
468 Fourth Avenue New York 16, N. Y.

BUCK, SEIFERT AND JOST
Consulting Engineers
(FORMERLY NICHOLAS S. HILL ASSOCIATES)
Specializing in Sewerage and Sewage Disposal, Water Supply and Water Purification, Valuations and Reports
Chemical and Biological Laboratories
112 East 19th Street New York 3, N. Y.

BURGESS & NIPLE
Civil and Sanitary Engineers
Established 1908
Sewage and industrial wastes disposal
Investigations, reports, design, rates
Laboratories, Plant Supervision
2015 W. Fifth Ave. Columbus 12, Ohio

BURNS & McDONNELL
Consulting and Designing Engineers
Kansas City 2, Mo.
P.O. Box 7088
Cleveland 14, Ohio
1404 E. 9th St.

ONLY $60 PER YEAR
is the cost of a professional listing in this space. A card here will identify your firm with the specialized sewage and industrial wastes field and will afford maximum prestige!

CAMP, DRESSER and McKEE
Consulting Engineers
Water Works and Water Treatment
Sewerage and Sewage Treatment
Municipal and Industrial Wastes
Investigations and Reports
Design and Supervision
Research and Development
Flood Control
6 Beacon St. Boston 8, Mass.

CAPITOL ENGINEERING CORPORATION
Engineers—Constructors—Management
SEWAGE SYSTEMS
Designs and Surveys
Planning
Bridges
WATER WORKS
Roads and Streets
Airports
Dams
Executive Offices
DILLSBURG, PENNSYLVANIA

THE CHESTER ENGINEERS
Water Supply and Purification
Sewage and Industrial Waste Treatment
Power Plants–Incineration–Gas Systems
Valuations–Rates–Management
Laboratory–City Planning
210 E. Park Way, Pittsburgh 12, Penna.

CHAS. W. COLE & SON
Engineers ~ Architects
Municipal Industrial
Commercial
220 W. LaSalle St., South Bend, Ind.
Phone 4-0127

CONSOER, TOWNSEND & ASSOCIATES
Water Supply—Sewerage—Flood Control & Drainage—Bridges—Ornamental Street Lighting—Paving—Light and Power Plants. Appraisals.
351 East Ohio St. Chicago 11, Ill.

Your firm should be listed here
. . . the most complete Directory available of consultants specializing in sewage and industrial wastes treatment.

It pays to secure competent and experienced engineering advice!

Damon & Foster

Consulting Civil Engineers and Surveyors

Sewerage, Sewage Disposal, Water Supply, Surveys, Land Subdivision, City and Town Planning, Reports, Design, Supervision

Sharon Hill, Pennsylvania

FREDERICK H. DECHANT
ENGINEER

Chairman of the Board, Frederic R. Harris Inc.

Water Works, Industrial Wastes, Sewerage, Recovery Processes, Hydraulic Works, Gas Plants

Philadelphia: Fidelity Phila. Trust Bldg.
New York: 27 William St.

DE LEUW, CATHER & COMPANY

Water Supply — Sewerage
Railroads — Highways
Grade Separation—Bridges—Subways
Local Transportation

Investigations — Reports — Appraisals
Plans and Supervision of Construction

150 North Wacker Drive — Chicago 6
505 Colorado Bldg. — Washington 5

CONSULTING ENGINEERS!

If you specialize in sewage and industrial waste disposal problems, prospective clients will expect to find your card in the Directory of Engineers contained in the . . .

Official Professional Journal of the Sewage and Industrial Wastes Field!

CATHODIC PROTECTION

Engineering—Surveys—Design—Installation

Electro Rust-Proofing Corp. (N.J.)
Belleville 9, New Jersey

FAY, SPOFFORD & THORNDIKE
ENGINEERS

JOHN AYER — RALPH W. HORNE
BION A. BOWMAN — WILLIAM L. HYLAND
CARROLL A. FARWELL — FRANK L. LINCOLN
HOWARD J. WILLIAMS

Water Supply and Distribution—Drainage
Sewerage and Sewage Treatment
Airports—Bridges—Turnpikes
Port and Terminal Works—Industrial Bldgs.

BOSTON — NEW YORK

FINKBEINER, PETTIS & STROUT

CARLETON S. FINKBEINER — CHARLES E. PETTIS
HAROLD K. STROUT

Consulting Engineers

Reports, Designs, Supervision,
Water Supply, Water Treatment, Sewerage,
Sewage Treatment, Wastes Treatment
Valuations & Appraisals

518 Jefferson Avenue — Toledo 4, Ohio

FREESE, NICHOLS AND TURNER

Consulting Engineers

2111 C & I Life Building
Houston 2, Texas
CH-1624

FROMHERZ ENGINEERS

Structural - Civil - Sanitary

Four Generations Since 1867

Water Supply; Sewerage; Structures; Drainage; Foundations
Industrial Waste Disposal
Investigations; Reports; Plans and Specifications; Supervision

823 1/2 Poydras St. — New Orleans, La.

Your firm should be listed here

. . . the most complete Directory available of consultants specializing in sewage and industrial wastes treatment.

EDWARD A. FULTON

Consulting Engineers

Investigations, Reports, Valuations, Design and Construction—Water Supply and Purification Plants; Sewerage and Sewage Treatment Works; Municipal Paving and Power Developments; Dams and Flood Control

3209 Brown Road — Saint Louis 14, Missouri

GANNETT FLEMING CORDDRY & CARPENTER, INC.
ENGINEERS

Dams, Water Works, Sewage, Industrial Wastes & Garbage Disposal, Highways, Bridges & Airports, Traffic & Parking—Appraisals, Investigations & Reports.

HARRISBURG, PENNA.

Branch Offices: Pittsburgh, Pa. Philadelphia, Pa. Daytona Beach, Fla. Pleasantville, N. J. Chesapeake, W. Va.

Take advantage of the services of these outstanding consultants!

GILBERT ASSOCIATES, INC.
Engineers and Consultants
Water Supply and Purification
Sewage and Industrial Waste Treatment
Chemical Laboratory Service
Investigations and Reports
New York 607 Washington St. Washington
Houston READING, PA. Philadelphia

GLACE AND GLACE
Consulting Sanitary Engineers
Sewerage and Sewage Treatment
Water Supply and Purification
Industrial Wastes Disposal
Design, Construction and Supervision of Operation
1001 N. Front Street Harrisburg, Pa.

GREELEY & HANSEN
Engineers
Samuel A. Greeley Paul Hansen (1920–1944)
Paul E. Langdon Kenneth V. Hill
Thomas M. Niles Samuel M. Clarke
Water Supply, Water Purification
Flood Control, Drainage, Refuse Disposal
Sewerage, Sewage Treatment
220 S. State Street, Chicago 4

ONLY $60 PER YEAR
is the cost of a professional listing in this space. A card here will identify your firm with the specialized sewage and industrial wastes field and will afford maximum prestige!

HASKINS, RIDDLE & SHARP
Consulting Engineers
Water Sewage
Industrial Wastes
Refuse Hydraulics
1009 Baltimore Ave. Kansas City 5, Mo.

HAVENS AND EMERSON
W. L. Havens C. A. Emerson
A. A. Burger F. C. Tolles F. W. Jones
H. H. Moseley J. W. Avery F. S. Palocsay
E. S. Ordway
Consulting Engineers
WATER, SEWERAGE, GARBAGE, INDUSTRIAL WASTES, VALUATIONS—LABORATORIES
Leader Bldg. Woolworth Bldg.
Cleveland 14, O. New York 7, N. Y.

HAZEN AND SAWYER
ENGINEERS
RICHARD HAZEN ALFRED W. SAWYER
Municipal and Industrial Water Supply
Purification and Distribution
Sewage Works and Waste Disposal
Investigations, Design,
Supervision of Construction and Operation
110 East 42nd Street New York 17, N. Y.

HENNINGSON, DURHAM & RICHARDSON, INC.
Consulting Engineers since 1917 for more than 600 cities and towns
Water Works, Light and Power, Sewers, Sewage Treatment, Reports, Flood Control, Appraisals, Drainage
Standard Oil Bldg. Omaha 2, Nebraska

HORNER & SHIFRIN
Consulting Engineers
W. W. HORNER E. E. BLOSS
H. SHIFRIN V. C. LISCHER
Airports — Hydraulic Engineering — Sewerage and Sewage Treatment — Water Supply — Municipal Engineering — Reports
Shell Building, St. Louis 3, Missouri

JONES, HENRY & WILLIAMS
Consulting Sanitary Engineers
Water Works
Sewerage & Treatment
Waste Disposal
Security Bldg. Toledo 4, Ohio

KEIS & HOLROYD
Consulting Engineers
Formerly Solomon & Keis
Since 1906
Water Supply and Purification, Sewerage and Sewage Treatment, Garbage and Refuse Disposal and Incineration, Industrial Buildings.
TROY, N. Y. FT. LAUDERDALE, FLA.

ENGINEERING OFFICE OF CLYDE C. KENNEDY
offers
COMPLETE ENGINEERING SERVICE
Investigations, Reports, Design
Supervision of Construction and Operation
Sewerage, Sewage Treatment and Industrial Waste Disposal
Chemical and Biological Laboratory
604 MISSION ST., SAN FRANCISCO 5

It pays to secure competent and experienced engineering advice!

MORRIS KNOWLES Inc.
Engineers
Water Supply and Purification, Sewerage and Sewage Disposal, Valuations, Laboratory, City Planning.
1312 Park Bldg. Pittsburgh 22, Pa.

Wm. S. Lozier Co.
Consulting Engineers
Sewerage, Sewage Disposal, Water Supply, Water Purification, Refuse Disposal
10 Gibbs Street Rochester, 4, N. Y.

GEORGE B. MEBUS
Consulting Engineer
Water Supply Sewage Treatment
Industrial Waste Treatment
NORTHWESTERN NATIONAL BANK BUILDING
GLENSIDE, PA.

CONSULTING ENGINEERS!
If you specialize in sewage and industrial waste disposal problems, prospective clients will expect to find your card in the Directory of Engineers contained in the . . .
Official Professional Journal of the Sewage and Industrial Wastes Field!

METCALF & EDDY
Engineers
Water, Sewage, Drainage, Refuse and Industrial Wastes Problems
Laboratory Valuations
Airfields
Statler Building
Boston 16

Nussbaumer, Clarke & Velzy, Inc.
Consulting Engineers
SEWAGE TREATMENT—WATER SUPPLY
INCINERATION—DRAINAGE
INDUSTRIAL WASTE TREATMENT
APPRAISALS
327 Franklin St., Buffalo, N. Y.
500 Fifth Ave., New York 36, N. Y.

PARSONS, BRINCKERHOFF HALL & MACDONALD
G. Gale Dixon, Associate
Civil and Sanitary Engineers
Water, Sewage, Drainage and Industrial Waste Problems.
Structures — Power — Transportation
51 Broadway New York 6, N.Y.

PIATT AND DAVIS
WM. M. PIATT P. D. DAVIS
Consulting, Designing, and Supervising Engineers
Water Works, Sanitary Sewers, Water Purification
Sewage Treatment, Public Buildings, Streets
Power Plants, Electrical Distribution
Reports and Appraisals
One Eleven Corcoran St. Bldg. Durham, N. C.

MALCOLM PIRNIE ENGINEERS
Civil and Sanitary Engineers
Malcolm Pirnie Ernest W. Whitlock
Robert D. Mitchell Carl A. Arenander
Malcolm Pirnie, Jr.
Investigations, Reports, Plans
Supervision of Construction and Operations
Appraisals and Rates
25 West 43rd Street New York 36, N. Y.

ONLY $60 PER YEAR
is the cost of a professional listing in this space. A card here will identify your firm with the specialized sewage and industrial wastes field and will afford maximum prestige!

LEE T. PURCELL
Consulting Engineer
Water Supply & Purification; Sewerage & Sewage Disposal; Industrial Wastes; Investigations & Reports; Design; Supervision of Construction & Operation
Analytical Laboratories
36 De Grasse St. Paterson 1, N. J.

THOMAS M. RIDDICK
Consulting Engineers and Chemists
Municipal and Industrial Water Purification, Sewage Treatment Plant Supervision, Industrial Waste Treatment
Laboratories for Chemical and Bacteriological Analyses
369 E. 149th St. New York 55, N.Y.

Take advantage of the services of these outstanding consultants!

RIPPLE AND HOWE
Consulting Engineers
O. J. RIPPLE B. V. HOWE
Appraisals—Reports
Design—Supervision
Water Works Systems, Filtration and Softening Plants, Reservoirs and Dams, Sanitary and Storm Sewers, Sewage Treatment Plants, Refuse Disposal, Airports
833-35 Twenty-Third St. Denver 5, Colorado

RUSSELL AND AXON
Consulting Engineers
Civil — Sanitary — Structural
Industrial — Electrical
Rate Investigations
408 Olive St., St. Louis 2, Mo.
Municipal Airport Daytona Beach, Fla.

SMITH and GILLESPIE
Consulting Engineers
All types of
Municipal Public Works & Utilities
Complete Services
P. O. Box 1048, Jacksonville, Fla.

STANLEY ENGINEERING COMPANY
Sewerage—Waterworks
Drainage—Flood Control
Electric Power—Airports
Hershey Building
Muscatine, Ia.

ALDEN E. STILSON & ASSOCIATES
Limited
Consulting Engineers
Water Supply—Sewerage—Waste Disposal
Bridges—Highways—Industrial Buildings
Studies—Surveys—Reports
209 S. High St. Columbus 15, Ohio

Your firm should be listed here
. . . the most complete Directory available of consultants specializing in sewage and industrial wastes treatment.

J. STEPHEN WATKINS
J. S. WATKINS G. R. WATKINS
CONSULTING ENGINEERS
Municipal and Industrial Engineering, Water Supply and Purification, Sewerage and Sewage Treatment, Highways and Structures, Reports, Investigations and Rate Structures.
251 East High Street Lexington, Kentucky
Branch Office
901 Hoffman Building Louisville, Kentucky

WERTZ ENGINEERING CO., Inc.
CONSULTANTS, DESIGNERS & CONSTRUCTORS
Water Supply & Purification
Sewage & Industrial Waste Treatment
Stream Pollution Studies
Chemical & Bact. Laboratory Service
441 North 2nd St. Reading, Pa.

WESTCOTT & MAPES, Inc.
Engineers
VALUATIONS—STUDIES—REPORTS
DESIGN—SUPERVISION
Industrial Waste Problems
Utilities—Industrial Plants
Commercial Buildings—Institutions
Public Works
New Haven, Connecticut

WESTON & SAMPSON
Consulting Engineers
Water Supply Water Purification
Corrosion Control
Sewerage, Sewage and Industrial Wastes Treatment
Stream Pollution Studies
Supervision, Valuation
Laboratory
14 Beacon Street Boston 8, Mass.

WHITMAN & HOWARD
Engineers (Est. 1869)
Sewerage, Sewage Disposal, Municipal and Industrial Development Problems, Water Supply, Water Purification, Water Front Improvements, Investigations, Reports, Designs, Supervision, Valuations
89 Broad Street, Boston, Mass.

WHITMAN, REQUARDT & ASSOCIATES
Engineers—Consultants
Civil — Sanitary — Structural
Mechanical — Electrical
Reports, Plans Supervision, Appraisals
1304 St. Paul Street Baltimore 2, Maryland

It pays to secure competent and experienced engineering advice!

THIS IS NO "BULL!"

"Flexibles" really solve sewer-cleaning problems!

Mexico City has a unique and serious sewer problem. Due to the settling of a large portion of the city, it is now approximately 20 feet lower than its sewer outlet, the Grand Canal. Until the condition is corrected and normal flow restored, there is a continuing problem of removing solids from the sewers, some of which are more than 300 years old. As a solution, the city has purchased over 200 "Flexible" Bucket Machines—one of which is pictured. Mexico City endorses "Flexibles" for their efficient performance and ease of operation and maintenance. We invite the opportunity to give your city an "on the job demonstration."

Write for our **FREE** *Catalog*

Flexible **SALES CORPORATION**

3786 Durango Ave., Los Angeles 34,

(DISTRIBUTORS IN PRINCIPAL CITIES)

AMERICA'S LARGEST LINE OF PIPE CLEANING TOOLS AND EQUIPMENT

INDEX TO ADVERTISERS

	Page
American Brass Company	409a
A. G. Chemical Company	390a, 391a, 417a
Builders-Providence, Incorporated (B-I-F Industries, Inc.)	383a
Cast Iron Pipe Research Association	388a, 389a
Chapman Valve Manufacturing Company	400a
Chain Belt Company	406a
Chicago Pump Company	381a
Clow, James B., and Sons (Iowa Valve)	399a
Combustion Engineering, Incorporated (Raymond Division)	407a
Dorr Company, The	412a
Fairbanks, Morse and Company	405a
Fischer and Porter Company	402a
Flexible Sales Corporation	424a
General Chemical Division (Allied Chemical and Dye Corp.)	408a
Hardinge Company, Incorporated	414a
Infilco Incorporated	397a
Johns-Manville Corporation	392a, 393a, 394a, 395a
Link-Belt Company	403a
Morse Boulger Destructor Company	396a
Pacific Flush Tank Company	410a
Rockwell Manufacturing Company (Nordstrom Valve Division)	401a
Simplex Valve and Meter Company	383a
Snow Gates and Valves	414a
United States Pipe and Foundry Company	415a
Vapor Recovery Systems Company	404a
Walker Process Equipment, Incorporated	413a
Wallace and Tiernan	Back Cover
Worthington Corporation (Public Works Division)	398a
Yeomans Brothers Company	387a
Zimmer and Francescon	416a

DIRECTORY OF ENGINEERS, pp. 418a–423a

Albright & Friel, Inc.
Alvord, Burdick & Howson
Anderson-Nichols & Company
Baffa, John J.
Baker, Michael, Jr., Inc.
Baxter & Woodman
Bets, W. H. & L. D.
Black & Veatch
Bogert & Childs
Bowe, Albertson & Associates
Brown & Blauvelt
Buck, Seifert & Jost
Burgess & Niple
Burns & McDonnell
Camp, Dresser & McKee
Capitol Engineering Corp.
Chester Engineers, The
Cole, Chas. W., & Son
Consoer, Townsend & Associates
Damon & Foster
Dechant, Frederick H.
De Leuw, Cather & Company
Electro Rust-Proofing Corp. (N. J.)
Fay, Spofford & Thorndike
Finkbeiner, Pettis & Strout
Freese, Nichols & Turner
Fromherz Engineers
Fulton, Edward A.
Gannett, Fleming Corddry & Carpenter, Inc.
Gilbert Associates, Inc.
Glace and Glace
Greeley & Hansen
Haskins, Riddle & Sharp
Havens and Emerson
Hazen & Sawyer
Hennington, Durham & Richardson, Inc.
Horner & Shifrin
Jones, Henry & Williams
Keis & Holroyd
Kennedy, Clyde C.
Knowles, Morris, Inc.
Lozier, Wm. S., Company
Mebus, George B.
Metcalf & Eddy
Nussbaumer, Clarke & Velzy, Inc.
Parsons, Brinckerhoff, Hall and Macdonald
Platt & Davis
Pirnie, Malcolm, Engineers
Purcell, Lee T.
Riddick, Thomas M.
Ripple & Howe
Russell & Axon
Smith & Gillespie
Stanley Engineering Company
Stilson, Alden E., & Associates
Watkins, J. Stephen
Wertz Engineering Company, Inc.
Westcott and Mapes, Inc.
Weston & Sampson
Whitman & Howard
Whitman, Requardt & Associates

PATRONIZE OUR ADVERTISERS—whose support makes possible the publication of this journal. *When writing advertisers be sure to mention SEWAGE AND INDUSTRIAL WASTES.*

LANCASTER PRESS, INC., LANCASTER, PA.

where's the best place to stop...

stream pollution

Stop it at the source. Stop it by disinfecting sewage plant effluent with chlorination by Wallace & Tiernan — often the most practical means of protecting streams, game fish and recreational areas.

W&T Chlorinators with operating ranges from .03 to 6000 pounds of chlorine per 24 hours are available to help you control both the bacteriological and the high B.O.D. load imposed on a receiving stream. Controls for manual, semi-automatic and fully automatic chlorinator operation provide flexibility to meet any particular problem.

In addition, W&T Chlorinators can satisfactorily control hydrogen sulfide odors in sewage trunk lines and at the plant, maintain a fresher non-septic influent, improve sedimentation, minimize sludge bulking and spray nozzle clogging and, also, remove algae to prevent filter ponding.

Write for additional information about the chlorinators which can make your plant more effective and help you stop at the source of stream pollution. There is no obligation.